Appendix N

Independent Risk Assessment

FINAL REPORT – REVISION 3

INDEPENDENT RISK ASSESSMENT FOR PORT AMBROSE LNG DEEPWATER PORT PHASE I

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AUGUST 19, 2014

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Acronyms & Abbreviations

AIS	Automatic Identification System
ALARP	As Low as Reasonably Practicable
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ATBA	Area-to-be-Avoided Zone
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
COLREG	International Convention for the Prevention of Collisions at Sea
DEGADIS	DEnse GAs DISpersion model
DOE	US Department of Energy
DOT	US Department of Transportation
DWP	Deepwater Port
DWPA	Deepwater Port Act
EIS	Environmental Impact Statement
ft	Feet
FEED	Front End Engineering Design
FERC	Federal Energy Regulatory Commission
CG-OES-2	USCG Office of Vessel and Facility Operating Standards
CG-OES-4	USCG Deepwater Ports Standards Division
HAZID	Hazard Identification
HIPPS	High Integrity Pressure Protection System
IGC	International Gas Code
IGIF	Inert Gas Injection Facility
IMO	International Maritime Organization
IRA	Independent Risk Assessment
ISM Code	International Safety Management Code
kg	kilogram
km	kilometer
kts	Knots
kW	kilowatt
LFL	Lower Flammability Limit
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carrier
LNGRV	Liquefied Natural Gas Regasification Vessel
m	meter
MARAD	Maritime Administration
min	minute
Mmscfd	million standard cubic feet per day
MTSA	Maritime Transportation Security Act
NAA	No Anchoring Area
NEPA	National Environmental Policy Act
NG	Natural Gas
nm	Nautical Mile
NOAA	National Oceanographic & Atmospheric Administration

PLEM	Pipeline End Manifold
RACA	Risk Assessment and Consequence Analysis
REM	Riser End Manifold
RS	Reynolds Stress
s	Second
SIGTTO	Society of International Gas Tanker and Terminal Operators
SOLAS	International Convention for the Safety of Life at Sea
SPM	Single-point mooring
STL	Submerged turret loading
TSS	Traffic Separation Scheme
UFL	Upper Flammable Limit
UNCLASS	Unclassified
USC	United States Code
USCG	U.S. Coast Guard
VTS	Vessel Traffic Service

Executive Summary

A. Background

On September 28, 2012, the U.S. Coast Guard (USCG) and U.S. Maritime Administration (MARAD) received an application from Liberty Natural Gas, LLC, for all Federal authorizations required for a license to own, construct and operate a Deepwater Port (DWP), known as Port Ambrose (Port Ambrose, or the Project) in the New York Bight (offshore of New York and New Jersey). Port Ambrose is designed solely for the delivery of natural gas. Liberty LNG will focus its deliveries during peak winter and summer months to provide additional supplies of natural gas to New York during periods of peak demand.

This document is a stand-alone technical report on the potential risks to the public from the proposed Port Ambrose project based on a large-scale release of Liquefied Natural Gas (LNG). The primary objective of this Independent Risk Assessment (IRA) is to assess impacts to humans and property not associated with the DWP from an event(s) that compromises LNG containment.

Port Ambrose is similar in design to two currently operating offshore LNG ports near Boston, Massachusetts and an approved port near Tampa, Florida. The Port Ambrose project would consist of two Submerged Turret Loading™ buoy (STL Buoy) systems (collectively, the DWP) in Federal waters approximately 16.5 nautical miles (nm) (30.56 kilometers (km)) southeast of Jones Beach, New York, and approximately 26.9 nm (49.63 km) from the entrance of New York Harbor (Figure 1-1), in a water depth of approximately 103 feet (ft) (31.39 meters (m)).

LNG would be delivered from purpose-built LNG regasification vessels (LNGRVs), vaporized on site and delivered through the STL buoys, flexible riser/umbilical, subsea manifold and lateral pipelines to a buried 19 nm (35 km) subsea mainline connecting to the existing Transco Lower New York Bay Lateral in New York State waters approximately 2.2 nm (4.1 km) south of Long Beach, New York and 13 nm (57 km) east of Sandy Hook, New Jersey. The buoys will be lowered to rest on a landing pad when not in use and would also include a pile-anchored mooring array.

The 145,000 cubic meter, membrane type LNGRVs would have onboard closed-loop vaporization and metering and odorant capability. Each vessel will have three vaporization units capable of a maximum send-out of 750 million standard cubic feet per day (MMscfd) (maximum pipeline system flow rate is 660 MMscfd with two buoys) with annual average expected to be 400 MMscfd. The LNGRVs have been designed to utilize a ballast water cooling system that will entirely re-circulate onboard the vessel during Port operations, eliminating vessel discharges associated with regasification while at the Port.

Deliveries through Port Ambrose would be focused during peak demand winter and summer months. The Port will receive up to 45 LNGRVs per year. As proposed, the LNGRVs would access the port inbound from the Hudson Canyon to Ambrose Traffic Lane and depart via the Ambrose to Nantucket Traffic Lane, Figure B.

If approved, the majority of the port and pipeline construction and installation are proposed to occur in 2015, with commissioning in December 2015.

B. Study Process

The deepwater port (DWP) license application review process includes an analysis of the proposed project's impacts on public safety based on a large scale release of LNG. The reference to "public" refers to human and property not associated with the DWP. The scope of the IRA does not include the natural gas sub-sea pipeline or any additional onshore gas pipeline or facilities.

As part of this analysis, a project's specific risk assessment is comprised of two parts:

- Phase I is an independent risk assessment (IRA) that evaluates potential maximum hazards of Liquefied Natural Gas (LNG) releases from credible scenarios (identification of the bounding or worst-credible consequences), as required by 33 CFR Part 148.105(y), and is an input to the Environmental Impact Statement (EIS) process.
- Phase II is a risk assessment (RA) that examines the range of scenarios that could result in an LNG release and evaluates proposed strategies to reduce the risk, providing input to Operations/Security (OPS/SEC) manuals required by 46 CFR 150.10 and potentially incorporating safety and security measures into the Marine Administrator's Record of Decision (ROD), as delegated by the Secretary of Transportation.

This report is limited to the Phase I IRA and involved six steps.

Table A: IRA Process

Step	Description
1. DWP Area Characterization	The DWP application was reviewed and additional data was gathered and analyzed about the port environment.
2. HAZID	Input was received from USCG, Sandia National Laboratories, federal, state and local emergency responders, law enforcement intelligence, pilots and the applicant to identify accidental and intentional scenarios.
3. Scenario Development	The HAZID scenarios were further analyzed to determine credible and bounding scenarios.
4. Vessel Collision and Frequency Analysis	Vessel traffic in the areas was analyzed to determine frequency of potential collisions.
5. Consequence Analysis	The impacts of the bounding cases were analyzed using Computational Fluid Dynamics (CFD) modeling to evaluate LNG spill and pooling and flammable vapor dispersion hazards. A solid flame model was used to evaluate the thermal radiation hazards.
6. Results and Conclusions	The analysis results were assessed and are presented in this report.

The conclusions of this IRA are presented as the hazard zones for thermal radiation and flammable vapor cloud dispersion for the accidental and intentional release scenarios evaluated. The hazard zones have been presented as graphical overlays on the nautical charts for the proposed Port Ambrose DWP project location. The results of the study are presented without passing judgment on the merits of the applicant's proposed project.

While the study evaluated the potential impacts to the public and surrounding infrastructure, it did not attempt to predict the number of estimated fatalities or injuries from these events. Also, the study was done without considering any mitigation measures that could be implemented to reduce the risk of accidental or intentional release of LNG from this proposed project. These considerations may be subject to further review outside of the scope of this study. Mitigation measure to reduce the risk associated with an LNG release will be discussed in the Phase II Risk Assessment.

The proposed Port Ambrose DWP falls within the proposed area of interest for the wind energy project(s) proposed for offshore New York as described in the Bureau of Ocean Energy Management's Call for Information of May 28, 2014 (79 FR 30645). The risk assessment will take this proposal into account; however, because of the lack of specific wind project details, this report is necessarily constrained in its ability to provide an analysis of the navigational safety risks that operation of the deepwater port may have on a future wind farm siting and operation. While it would be inappropriate for this report to purport to establish specific setbacks between the deepwater port, vessels operating in the area, and the wind farm, this report does provide information on LNG spill consequences which will help inform any future offshore wind energy project proponent on future siting of wind turbines. To the extent practicable, in the absence of a detailed wind farm application, the Phase II portion of the IRA will examine navigational safety concerns and consider measures that may serve to mitigate potential risks of both facilities operating in the same geographic area.[1]

C. Results

C.1 Scenarios Selected

The scope of the HAZard IDentification (HAZID; Step 3, Table A) was the identification of “credible” scenarios for accidental and intentional events involving all parts of the proposed project under the jurisdiction of the USCG. Credible scenarios as defined in the HAZID process do not necessarily represent scenarios that are high risk. They are possible intentional and accidental scenarios identified through a multidisciplinary team evaluation of the project. The scenarios are identified regardless of likelihood and are used in the Phase I IRA for bounding the consequences of concern.

C.2 Consequence Modeling Results

Thermal radiation hazard distances from a pool fire were estimated to two different thermal heat flux levels:

- 37.5 kW/m^2: Damage to process equipment and storage tanks[2] for unprotected exposures based on an average 10-minute exposure duration, as well immediate fatalities

[1] This IRA does not establish enforceable requirements on any potential future wind farm operator. The BOEM may consider this information as it determines what, if any, operational restrictions may need to be imposed on a proposed wind farm. Pursuant to the Memorandum of Agreement between (then) BOEMRE and the USCG (dtd 27Jul2011), the USCG will assist BOEM in assessing the navigational risks that may be posed by renewable energy development, For additional information, see Navigation and Vessel Information Circular, 02-2007, “Guidance on the Coast Guard’s Roles & Responsibilities for Offshore Renewable Energy Installations (OREI).”
[2] Barry, Thomas, *Risk-Informed Performance-based Industrial Fire Protection* (Knoxville, TN: Tennessee Valley Publishing, 2002).

- 5 kW/m^2: Permissible level for emergency operations lasting several minutes with appropriate clothing based on an average 10-minute exposure duration[3] and onset of second degree burns based on an average 40-second exposed duration[4]

The maximum thermal radiation hazard and flammable vapor dispersion distances predicted for the intentional and vessel collision scenarios are listed in Table B. In this IRA, it is assumed that all spills originate at the LNGRV, with all hazard distances measured from the center of the LNG pool.

The flammable vapor dispersion hazard distance is determined as the maximum downwind distance to the Lower Flammability Limit (LFL). The flammable vapor cloud dispersion simulations were performed using FLACS, a commercial Computational Fluid Dynamics (CFD) code. Given the right environmental conditions, the maximum distances could occur in the direction of prevailing wind at the time of release from the LNG release source. The weather data for the Port Ambrose site is detailed in Section 3.5. The specific modeling parameters for the consequence analysis are detailed in Section 7.4.

All distances in Table B are measured from the center of the pool, which is the source of the LNG release. Note that the maximum pool diameters are different for the pool fire and vapor cloud dispersion cases. This is due to different boundary conditions (e.g., fire vs. no fire) as well as the different model applied to the analysis (e.g., equilibrium mass balance for pool fire vs. dynamic CFD model for vapor dispersion).

Table B: Summary Risk Analysis Consequences for Bounding Scenarios

Result	Scenario 1 (Intentional)	Scenario 2 (Intentional)	Scenario 6 (Collision)
Breach Size, m^2	16	12	23.1
Number of Tanks	1	2	1
Total Capacity of Impacted Tank(s), m^3	41,429	82,857	41,429
Release Quantity, m^3	29,000	58,000	29,000
Pool Fire Maximum Distance to Endpoint (meters)			
Pool Diameter, m	579	709	696
Thermal Radiation Endpoint > 37.5kW/m^2	970	1,110	1,090
Thermal Radiation Endpoint > 5 kW/m^2	2,270	2,640	2,600
Flammable Vapor Cloud Dispersion (No Ignition)			
Maximum Pool Diameter (m)	533	556	541
Distance to LFL, m	2,800	3,550	2,750

These scenarios represent the bounding thermal radiation hazards for the intentional and vessel collision scenarios. A pool fire at either Buoy #1 or Buoy #2 would not impact the other buoy location from a sustained fire at the 37.5 kW/m^2 and 5 kW/ m^2 radiation levels. Additionally, the safety fairway is not impacted at these radiation levels.

[3] Ibid.
[4] Federal Emergency Management Agency, *Handbook of Chemical Hazard Analysis Procedures*, (Washington, DC: FEMA, 1989).

As compared to the pool fire consequence, where the thermal radiation hazard extends radially from the pool fire center, the flammable vapor dispersion hazard will extend as a cloud dispersing in the downwind direction of the prevailing wind. .

The intentional scenario (Scenario 2) results in the greatest distance to LFL, and an intentional incident at either buoy could potentially impact the other buoy location. Assuming the wind direction was toward a second LNGRV at the adjacent buoy (see Figure 3-5). However, given a dispersion duration of over 20 minutes to the other buoy location, the other LNGRV has an emergency buoy disconnect that can shutdown regasification and disconnect the LNGRV in 15 minutes.

In addition to impacting the other buoy, the dispersion distance to LFL from Scenario 2 (from Buoy #2) could also impact Ambrose to Nantucket lane, depending on the wind direction (see Figure 3-5) at the time of release. As discussed above, a similar dispersion time of over 20 minutes is predicted for the cloud to reach the shipping lane.

C.3 Frequency of Events

The total frequency of a collision with an LNGRV at the DWP was calculated for two vessel types: 1) vessels in the established Ambrose to Nantucket lane and the Hudson Canyon to Ambrose lane, and 2) vessels randomly passing the DWP location. This calculation utilized vessel traffic from the Automatic Identification System (AIS) dataset provided for this project by the USCG R&D Center, and only included those vessels with the potential to breach the inner hull of the LNGRV (resulting in a release of LNG from containment) in a collision.

Due to the distance between the DWP and the vessels in the two adjacent traffic lanes, the likelihood of a powered and drifting collision from vessels in these defined routes and the LNGRV was unlikely. In addition to vessels in the defined fairway, vessels of sufficient displacement and speed were identified that passed near the DWP. Using the collision frequency calculation for randomly distributed vessels, the likelihood for these vessels colliding with the DWP was calculated. However, given the small number of random vessels and the size of the LNGRV, the likelihood is also unlikely.

The collision frequency for the proposed DWP considering both vessels in the two adjacent traffic lanes and randomly distributed around the DWP is shown in Table C.

Table C: Frequency of Vessel Collisions for Proposed DWP

TRAFFIC LOCATION	ANNUAL FREQUENCY OF COLLISION (COLLISION PER YEAR)	COLLISION ESTIMATED PERIOD (YEARS PER COLLISION)
Ambrose to Nantucket Lane	2.13×10^{-5}	1 collision every 47,000 years
Hudson Canyon to Ambrose Lane	7.98×10^{-9}	1 collision every 125,000 years
Randomly Distributed	1.67×10^{-8}	1 collision every 60,000 years
TOTAL	$\mathbf{2.13 \times 10^{-5}}$	**1 collision every 47,000 years**

1.0 Project Overview

The Secretary of Transportation is authorized under the Deepwater Port Act[5] to issue licenses for the ownership, construction and operation of deepwater ports.[6] This includes liquefied natural gas (LNG) facilities. The Secretary delegated authority for processing license applications to the U.S. Coast Guard (USCG) and the U.S. Maritime Administration (MARAD).

To enable a more efficient application review process, the USCG established procedures for license applicants to hire third-party consultants, under direction of the USCG, to conduct statutorily required analyses (e.g., Environmental Impact Statements (EISs) and Independent Risk Assessments (IRAs))[7].

1.1 Introduction

On September 28, 2012, the USCG and MARAD received an application from Liberty Natural Gas, LLC, for all Federal authorizations required for a license to own, construct, and operate a deepwater port (DWP) called Port Ambrose. The USCG deemed the application complete subsequent to a review as required by the Deepwater Port Act (DWPA).

1.2 The Independent Risk Assessment (IRA)

This IRA is submitted by AcuTech Consulting Group (AcuTech) to the USCG for the proposed Port Ambrose, LNG DWP Project. This IRA provides the necessary data for the public safety section of the EIS being developed for the Project. AcuTech is the lead contractor for the IRA, responsible for the development of a stand-alone technical report on the potential risks to the public from potential large-scale release(s) of LNG or natural gas. Under contract to AcuTech, GexCon US (GexCon) conducted the modeling for liquid spills, fire, and vapor dispersion for the LNG release scenarios defined in the IRA. This included use of a three-dimensional computational fluid dynamics (CFD) model for the flammable dispersion consequences.

AcuTech is a global company providing consulting, training, and technologies to the public and private sectors to identify, evaluate, and manage risks in order to continually improve safety, security, health, environmental, and operational performance. AcuTech has expertise in LNG operations, security, process safety, offshore hazardous materials installation operations, risk assessment, fire protection, and homeland security for critical infrastructure.

GexCon US has vast experience performing LNG hazard analyses and probabilistic risk assessments for LNG plants. Staff expertise includes consequence modeling for LNG vapor cloud dispersion, thermal radiation from LNG pool fires and vapor cloud explosion scenarios. Their CFD model, FLACS, enables LNG pool spreading and vapor cloud dispersion in one unified environment.

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[5] Deepwater Port Act (DWPA) of 1974 as amended by the Maritime Transportation Security Act of 2002 (MTSA); 33 United States Code 1501, *et seq* and Coast Guard and Marine Transportation Act of 2012

[6] The term "deepwater port" refers to any fixed or floating manmade structures other than a vessel, or any group of such structures, located beyond the territorial sea and of the coast if the United States, and intended for the loading or unloading and further handling of oil for transportation, except as excluded in 33 U.S.C. 1522.

[7] *Guidance on Assessing the Risks and Consequences of a Liquefied Natural Gas (LNG) Deepwater Port*, U.S. Department of Homeland Security, U.S. Coast Guard, October 2010.

The purpose of this work is to develop a stand-alone technical report on the potential risks to the public from the proposed Port Ambrose DWP based on a large scale release of LNG. The reference to "public" refers to human and property not associated with the DWP.

The scope of the IRA does not include the natural gas sub-sea pipeline or any additional onshore gas pipeline or facilities.

The assessment is not a full probabilistic risk assessment which estimates the cumulative frequency of all expected losses over the life of the DWP facilities, but instead is a deterministic study of the most significant credible loss scenarios that represent the maximum expected impacts from accidental and intentional scenarios developed and defined as part of the IRA. As such, the study provides representative scenarios for consideration and derives the most significant consequences (defined as the bounding intentional and accidental scenarios) for presentation of the maximum expected impacts to public safety.

The USCG Office of Operating and Environmental Standards, Deepwater Ports Standards Division (CG-OES-4) directed the scope, content, and quality of the report. The applicant, Liberty Natural Gas, LLC, had no technical direction of the work conducted under this contract, and was not able to review the work product before its release to the public. The applicant did, however present an overview of the Port Ambrose project to the IRA team as part of the HAZard IDentification (HAZID), and answered additional questions as requested.

1.3 Proposed Port Ambrose Deepwater Port

Liberty Natural Gas, LLC is proposing to construct, own, and operate a DWP offshore of New York and New Jersey. Port Ambrose is similar in design to the licensed and commissioned Northeast Gateway and Neptune DWPs offshore Boston, Massachusetts, and to Port Dolphin DWP, located offshore Tampa, Florida, which has received a license from MARAD, but which has not started construction. The unloading portion of the proposed Port Ambrose DWP, would be located in federal waters approximately 16.5 nm (30.56 km) off Jones Beach, New York, approximately 26.9 nm (49.63 km) from the entrance to New York Harbor, in a water depth of approximately 103 ft (31.39 m). The location of the offshore components of the project is illustrated in Figure 1-1.

As shown in Figure 1-1, the DWP would be located between designated shipping fairways which would allow LNG carriers to approach and depart without interfering with existing traffic.

The DWP would consist of two buoys 1.65 nm apart. LNG would be delivered from purpose-built LNG regasification vessels (LNGRVs), vaporized on site and delivered through the Submerged Turret Loading (STL) buoys, flexible riser/umbilical, subsea manifold and lateral pipelines to a buried 19 nm (35 km) subsea mainline connecting to the existing Transco Lower New York Bay Lateral in New York State waters, approximately 2.2 nm (4.1 km) south of Long Beach, New York and 13 nm (57 km) east of Sandy Hook, New Jersey. The buoys would be lowered to rest on a submerged landing pad when not in use and would also include a pile-anchored mooring array.

The coordinates of the proposed buoys of the DWP are illustrated in Figure 1-2.

Figure 1-1: Port Ambrose Proposed Project Location

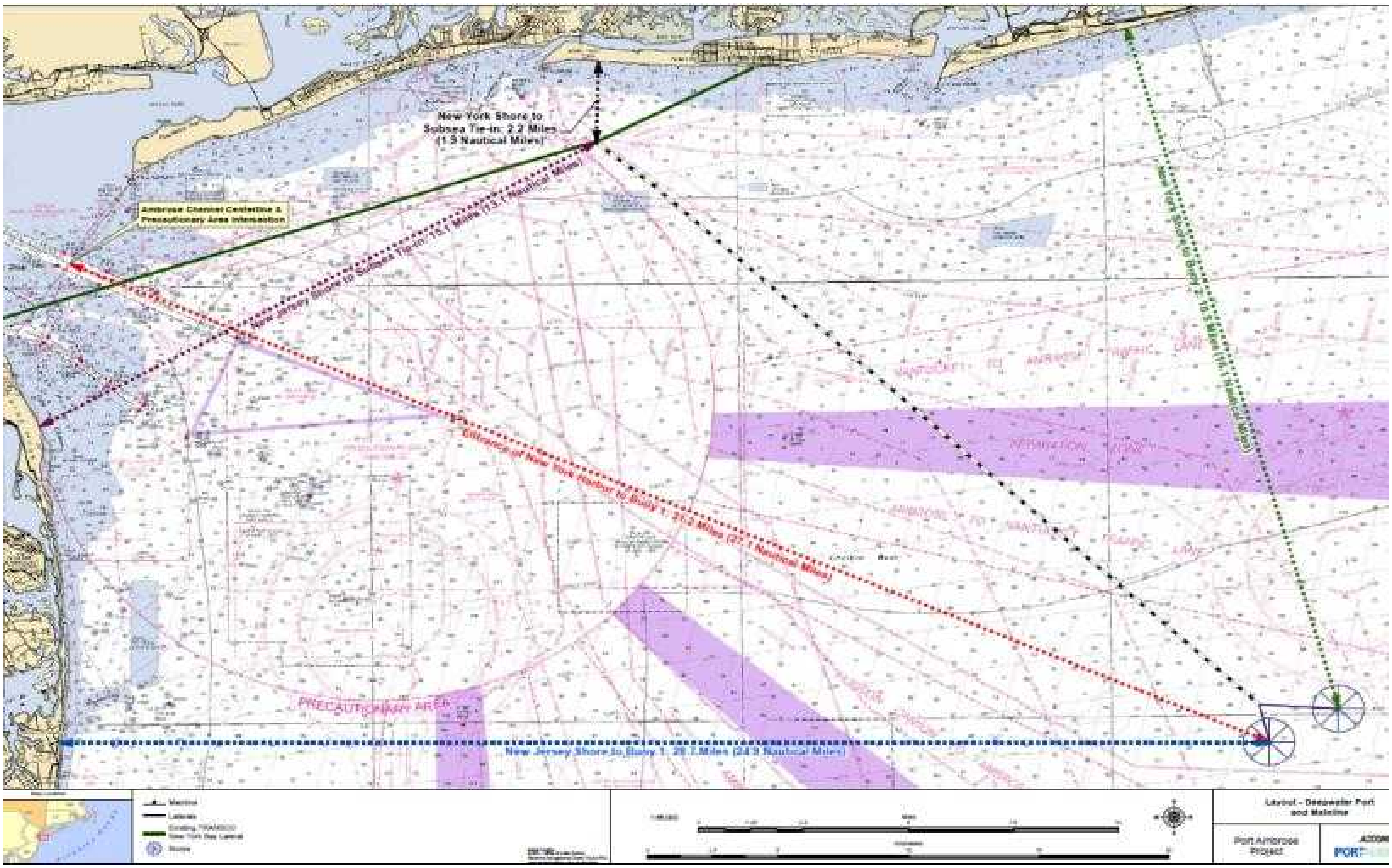
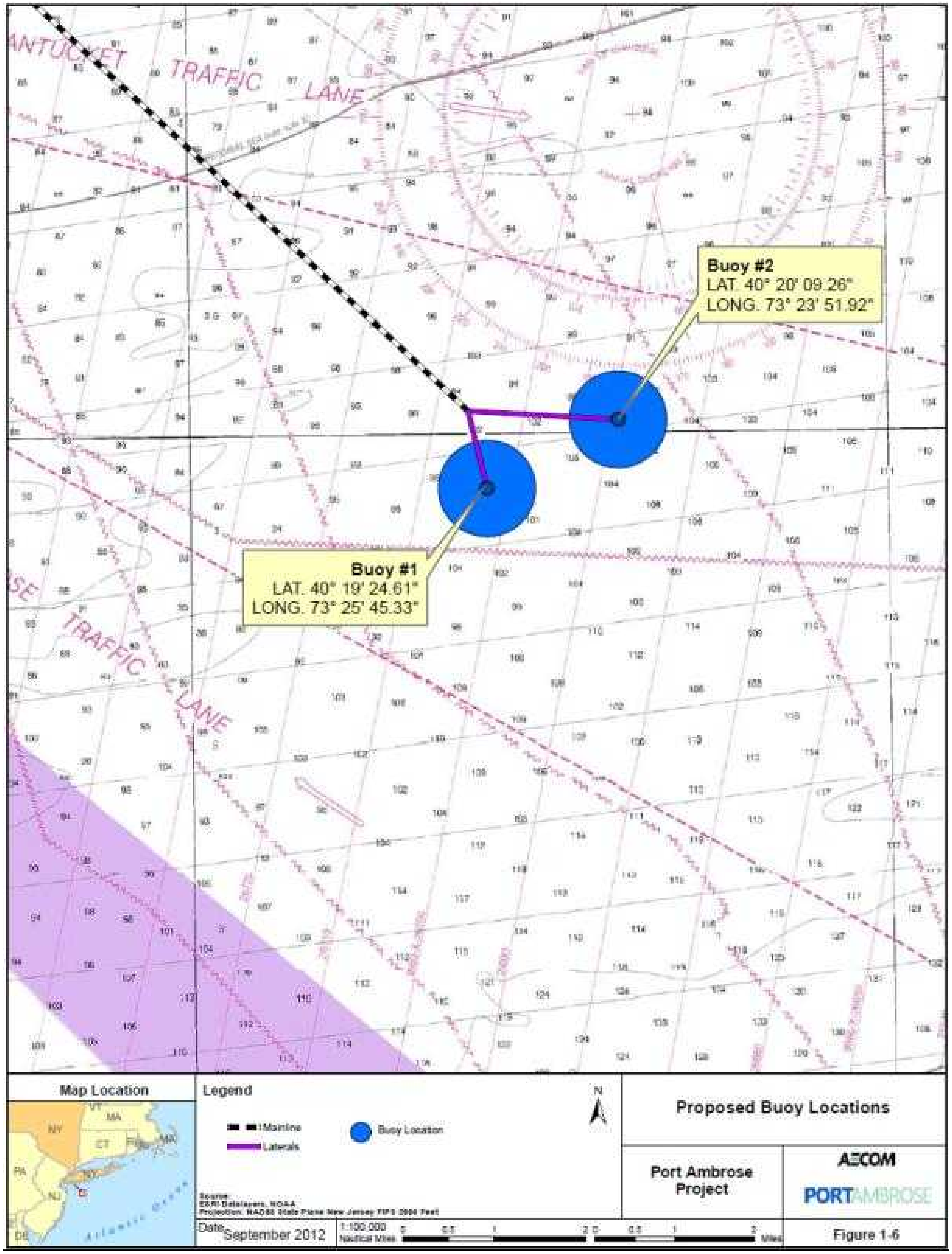


Figure 1-2: Unloading Buoy Coordinates



As part of the DWP, Port Ambrose would be capable of mooring Shuttle and Regasification Vessels (LNGRVs), as depicted in Figure 1-3. The LNGRVs are standard LNG tankers that have been built or modified to connect with the STL Buoys and delivery of natural gas to ports like the proposed Port Ambrose Project. The LNGRVs will be capable of transporting approximately 3.2 billion cubic feet (bcf) of natural gas condensed to approximately 5.1 million cubic feet (MMcf or 145,000 m^3) of LNG.

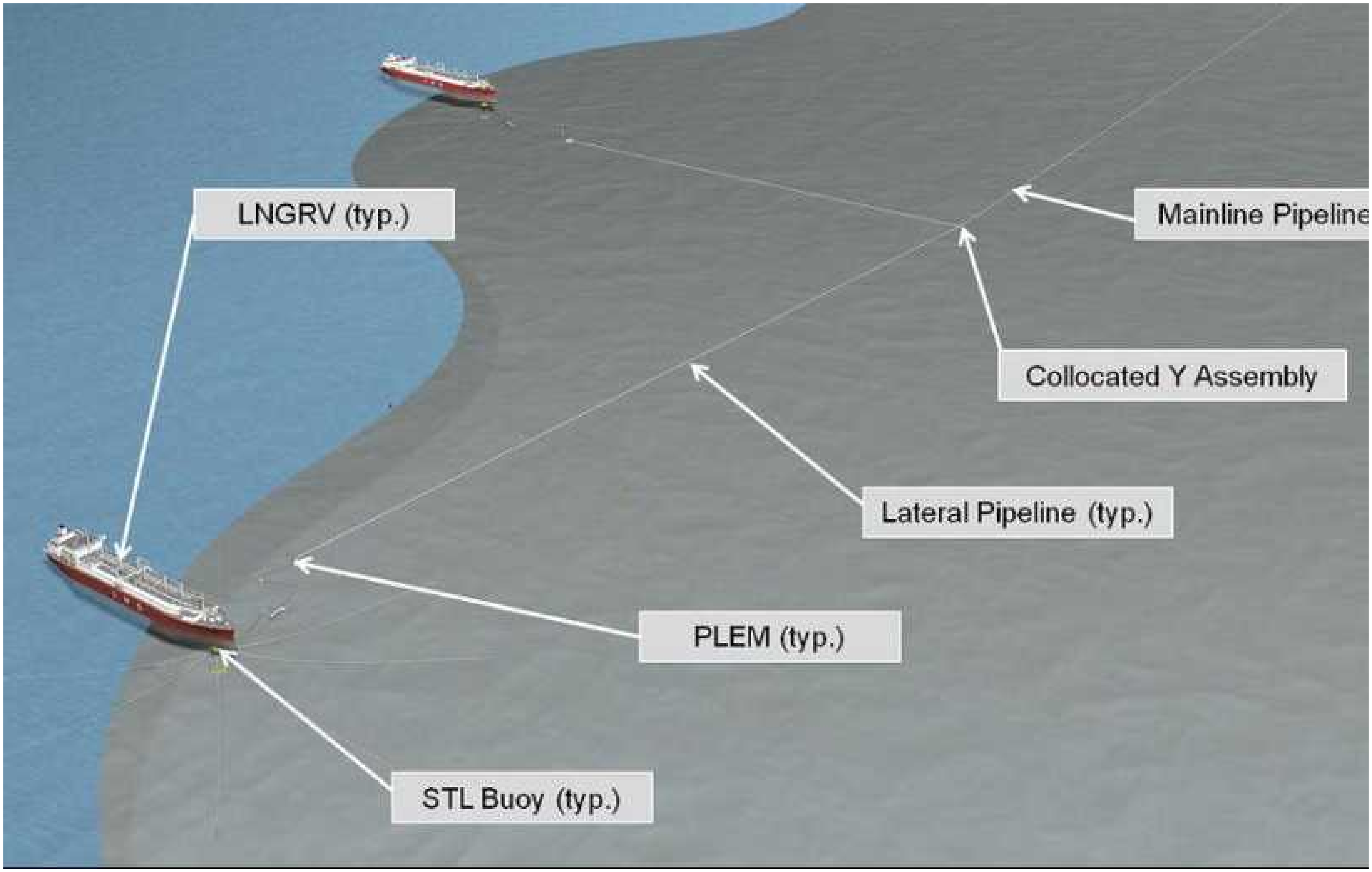
The vessels will have onboard regasification equipment to convert the LNG into pipeline quality natural gas. It is anticipated that each vessel will produce natural gas at an annual average throughput rate of 400 MMcf/d, and a peak rate of 660 MMcf/d with one or two vessels stationed at the Port. Both the newly arrived and soon-to-depart LNGRVs may be transferring gas simultaneously to ensure uninterrupted flow during peak demand.

Figure 1-3: LNG Regasification Vessel (LNGRV) Illustration

Figure 1-4 illustrates that the Port Ambrose project will be capable of mooring up to two LNGRVs simultaneously for uninterrupted off-loading and transmission of natural gas to onshore interconnection stations for delivery to customers in the New York Area.

In addition to the LNGRVs, Liberty Natural Gas, LLC will include a support vessel as part of the project. The specifics of the LNGRVs and the additional project vessel are discussed in detail as part of Section 3.

Figure 1-4: DWP Illustration



2.0 Risk Assessment Methodology

2.1 Study Basis

In order to provide useful quantitative data regarding the potential safety and security impacts of the proposed Port Ambrose Deepwater Port (DWP) project, this assessment follows the practices used in earlier Independent Risk Assessments (IRAs) conducted under the guidance of the U.S. Coast Guard (USCG) Deepwater Ports Standards Division (CG-OES-4). The objectives of the study are:

- Evaluate the potential risks utilizing appropriate site-specific data and credible scenarios to address public safety issues associated with the storage, handling, regasification, and transportation of LNG at the proposed the DWP.
- All analysis is transparent and available for review to the greatest extent possible by the public and government agencies, subject to limitations imposed by security requirements.
- Establish an independent and project-specific analysis, in lieu of extrapolation or regression of past studies or calculations.
- Follow the guidance for accidental and intentional LNG spills on water based on work conducted by Sandia National Laboratories (Sandia) and documented in the following Department of (DOE) reports[8]:
  - *Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water*, 2004
  - *Breach and Safety Analysis of Spills Over Water from Large Liquefied Natural Gas Carriers*, 2008

This IRA relied on input and guidance from experts at Sandia, the USCG, federal, state and local emergency responders, law enforcement intelligence, and pilots in the development of the intentional and accidental scenarios considered.

2.2 Bounding Scenarios and Credibility

Any scenario considered in the IRA needs to be credible. This objective was achieved by developing the scenarios through the HAZard IDentification (HAZID) process which used a multidisciplinary team to propose intentional and accidental scenarios. No scenario was dismissed at this stage of the project based on likelihood. Events that result in significant consequences, but are highly unlikely, were included and represent bounding cases. To converge to this set of bounding scenarios, the following principles of scope were applied:

- The assessment is a systems level risk assessment that considers operations related to the transfer, storage, and regasification at the DWP.
- The full range of hazards was evaluated as part of an initial HAZID.
- The assessment analyzed a defined subset of the HAZID cases to bracket the credible range of potential accidental and intentional LNG release scenarios.

[8] SAND2004-6258 and SAND2008-3153

2.3 Significance Criteria and Assumptions

To determine the impact to the public, various hazard criteria must be used. The hazards of interest in the IRA are first that of thermal radiation from potential pool fires. The results calculated here are compared to criteria prescribed by USCG in the Statement of Work and include SAND2008-3153 baseline criteria. Thermal radiation hazard distances from a pool fire were estimated to two different thermal heat flux levels:

- 37.5 kW/m^2: Damage to process equipment and storage tanks,[9] for unprotected exposures based on an average 10-minute exposure duration, as well immediate fatalities
- 5 kW/m^2: Permissible level for emergency operations lasting several minutes with appropriate clothing based on an average 10-minute exposed duration[10] and onset of second degree burns based on an average 40 second exposed duration[11]

The pool fire calculations report the maximum distance to each of these thermal radiation endpoints, estimated respectively from the center of the pool fire.

In addition to the thermal radiation hazards from pool fires, the vapor dispersion from an unignited cloud resulting from spilled LNG is of interest. To determine the hazard levels associated with this potential event, the distance to the lower flammability limit (LFL) endpoint, which is 5% by volume for methane, is also reported.

These modeling endpoints were considered from spills emanating from a pool assumed to be initiated from either accidental or intentional release scenarios at the DWP location itself. While the hazard zones would also apply to the LNG regasification vessels (LNGRVs) in transit to the DWP, the figures in this report depict a pool that is centered at the buoy with the release originating at the LNGRV. The significance criteria are limited specifically to acute and fatal effects to the public (either in nearby waters or on shore). Scenarios involving long-range transport to or from the source of the LNG were not included as they are outside the jurisdiction of the USCG.

2.4 Study Approach

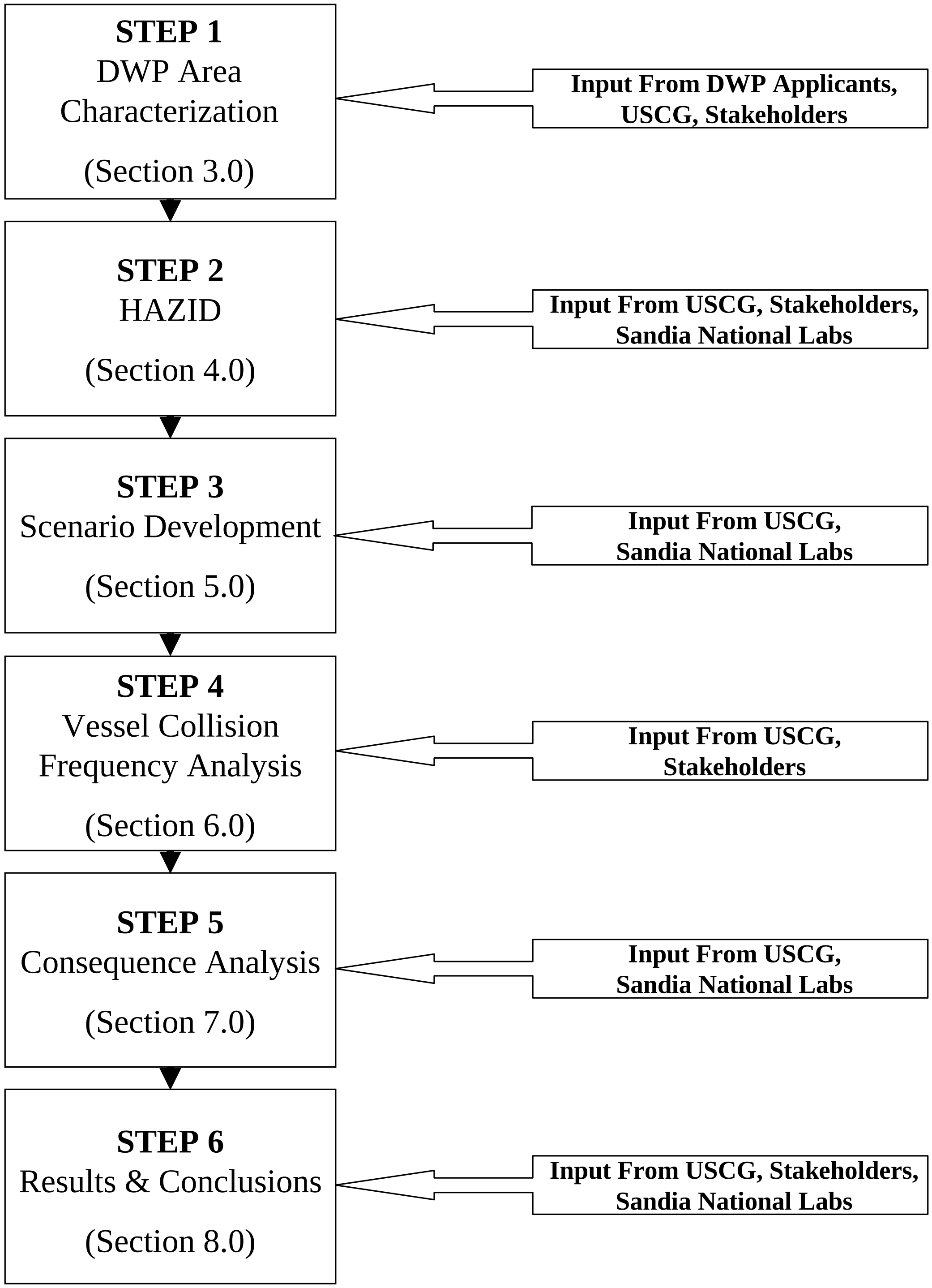
Figure 2-1 illustrates the risk assessment approach that was used to complete the analysis of this LNG DWP project. The approach was comprised of 6 steps, and included:

- **Step 1 – DWP Area Characterization**: Section 3 discusses the input data that was collected and reviewed for the risk assessment. The data included a description of the LNG DWP project, specifics on the design of the DWP location, expected size of the LNGRVs, operating conditions of the offloading, storage and regasification operation, and information on the marine traffic in the area of the proposed DWP location.

[9] Barry, Thomas, *Risk-Informed Performance-based Industrial Fire Protection* (Knoxville, TN: Tennessee Valley Publishing, 2002).
[10] Ibid.
[11] Federal Emergency Management Agency, *Handbook of Chemical Hazard Analysis Procedures*, (Washington, DC: FEMA, 1989).

- **Step 2 - HAZID**: The HAZard IDentification (HAZID) is a structured evaluation exercise that was used to identify accidental and intentional releases scenarios for this LNG DWP project. As discussed in Section 4, AcuTech facilitated a team consisting of representatives from USCG, Sandia National Laboratories, federal, state and local emergency responders, law enforcement intelligence, and pilots to identify initiating accidental and intentional events and a qualitative estimate of the potential consequences.
- **Step 3 – Scenario Development**: The development of the list of accidental and intentional scenarios evaluated in this risk assessment is discussed in Section 5. The final list of scenarios was determined by grouping similar cases from the HAZID, as well as screening out cases based on likelihood of occurrence and/or resulting consequence level, to identify the bounding accidental and intentional release scenarios for this project. Step 3 also includes a discussion of the development of the accidental and intentional release sizes. The intentional release sizes were selected based on guidance provided in SAND2008-3153 and guidance provided by Sandia specific to this project.
- **Step 4 – Vessel Frequency Collision Analysis**: Section 6 details the marine vessel traffic analysis and overall statistical likelihood of the occurrence of a vessel collision or allision with an LNGRV located at the DWP buoy locations.
- **Step 5 – Consequence Analysis**: Section 7 details the assumptions and consequence models that were used to evaluate the release scenarios defined in Step 3. This includes: LNG spill rate, pool formation and evaporation, vapor dispersion, and thermal radiation models that were used in the analysis. A solid flame model was used to calculate the thermal hazard zones and a Computational Fluid Dynamics (CFD) model was used for determining the consequences associated with vapor dispersion.
- **Step 6 – Results & Conclusions**: Section 8 combines the inputs and results of the supporting sections to evaluate the risk of this DWP project. This final step includes a discussion of the potential impacts to the public from the LNG DWP project based on the distances to the thermal radiation and flammable vapor dispersion endpoints for the accidental and intentional release scenarios modeled in the risk assessment.

Figure 2-1: DWP IRA Process



3.0 Deepwater Port Area Characterization

This section provides information to characterize and describe the proposed project area off the coast of New York and New Jersey. Information in this section is derived from the applicant's materials. Most of the information is summarized from Port Ambrose's Deepwater Port (DWP) license application (Volumes I and II General (Public)).

3.1 Proposed Port Ambrose DWP

As discussed in Section 1.3, the proposed DWP, would be located in federal waters approximately 16.5 nm (30.56 km) off Jones Beach, New York, approximately 26.9 nm (49.63 km) from the entrance to New York Harbor, in a water depth of approximately 103 feet (31.39 m). LNG would be delivered through a flexible riser/umbilical, subsea manifold and lateral pipelines to a buried 19 nm (35 km) subsea Mainline connecting to the existing Transco Lower New York Bay Lateral in New York State waters.

The components of the Project will consist of the following:

- Two (2) Submerged Turret Loading (STL) Buoy systems, comprised of the following components for each system:
    - Flexible risers;
    - Umbilicals;
    - STL Buoy pick-up assembly, which will incorporate floating messenger lines with marker buoys;
    - STL Buoy anchor points and mooring lines;
    - STL Buoy landing pads; and
    - Pipeline end manifolds (PLEMs);
- Two (2) Laterals, 0.76 nm (1.41 km) and 1.54 nm (2.85 km) in length, which will connect the PLEMs to the Mainline;
- The Mainline, which will be 19.00 nm (35 km) long and will connect to the Transco Lower New York Bay Lateral (Transco) pipeline, and;
- Subsea tie-in (SSTI) and hot-tap connections at the Transco pipeline.

3.1.1 LNG Regasification Vessels

Port Ambrose would be capable of mooring two LNG Regasification Vessels (LNGRVs). The LNGRVs are designed to carry liquefied natural gas and also to re-gasify the natural gas prior to off-loading for transport to shore. These vessels would have a capacity up to 145,000 cubic meters (m^3) of LNG, transported and stored at a temperature of -261° F (-162 ° C). Table 3-1 describes the approximate dimensions and capacities of the proposed LNGRVs that are expected to call on this DWP.

Table 3-1: Typical Dimensions and Capacities of 145,000 m^3 LNGRV

Item	Description
Hull Type	Double bottom/Double hull
Total LNG Capacity	145,000 m^3 (5,120,780 ft^3)
Number and Type of Cargo Tanks	4
Length Overall	280 m (918 ft)
Molded Breadth	44 m (142 ft)
Design Draft	11.4 m (37.4 ft)
Laden Displacement (estimated)	104,000 tonnes
Vessel Speed (calm weather)	19.5 Knots (kts)

The vessels anticipated to call on the Port will be custom-built LNGRVs.

All LNGRVs calling on the Port will have onboard vaporization and metering equipment able to convert the LNG into pipeline quality natural gas suitable for transportation in the existing natural gas pipeline system. The regasification facilities on the LNGRV will be operated using at least 99 percent natural gas, which will help ensure that Port Ambrose has minimal impact on air quality during regasification operations, and will operate as a "Closed Loop" system, which does not rely on drawn seawater as the heat source for regasification; therefore, there is no seawater intake or discharge used specifically for the regasification process. The LNGRVs will utilize a specially-designed ballast water cooling system that will entirely recirculate on board the vessel during Port operations, thus eliminating any vessel discharges while at the Port.

Liberty anticipates that the LNG will be sourced primarily from the Caribbean Islands of Trinidad and Tobago, which is historically the source of most LNG imports into the U.S.

3.1.2 LNGRV Offloading Operation

Once the LNG has been converted, it will be offloaded through the STL Buoys, into the Laterals, and then into the Mainline. Each LNGRV will moor at the Port for between five (5) to sixteen (16) days to complete the unloading process, depending on vessel size and natural gas send-out rate. The two separate buoys would allow natural gas to be delivered in a continuous flow, without interruption, by scheduling an overlap between arriving and departing LNGRVs. It is anticipated that the DWP would host 30-45 vessels per year.

The unloading buoy technology and associated equipment proposed for Port Ambrose is similar to that used offshore in projects for Massachusetts and in Florida.[12] The technology has also been successfully used in the offloading of oil and natural gas at several locations overseas, including the North Sea. Each unloading buoy would have eight mooring lines consisting of wire rope and chain. The mooring lines would connect each unloading buoy to eight anchor points most likely consisting of driven piles on the seabed. The unloading buoy is designed by Advanced Production and Loading (APL), and is also commonly known as a Submerged Turret Loading (STL) buoy. See Figure 3-1 for an illustration of the STL system.

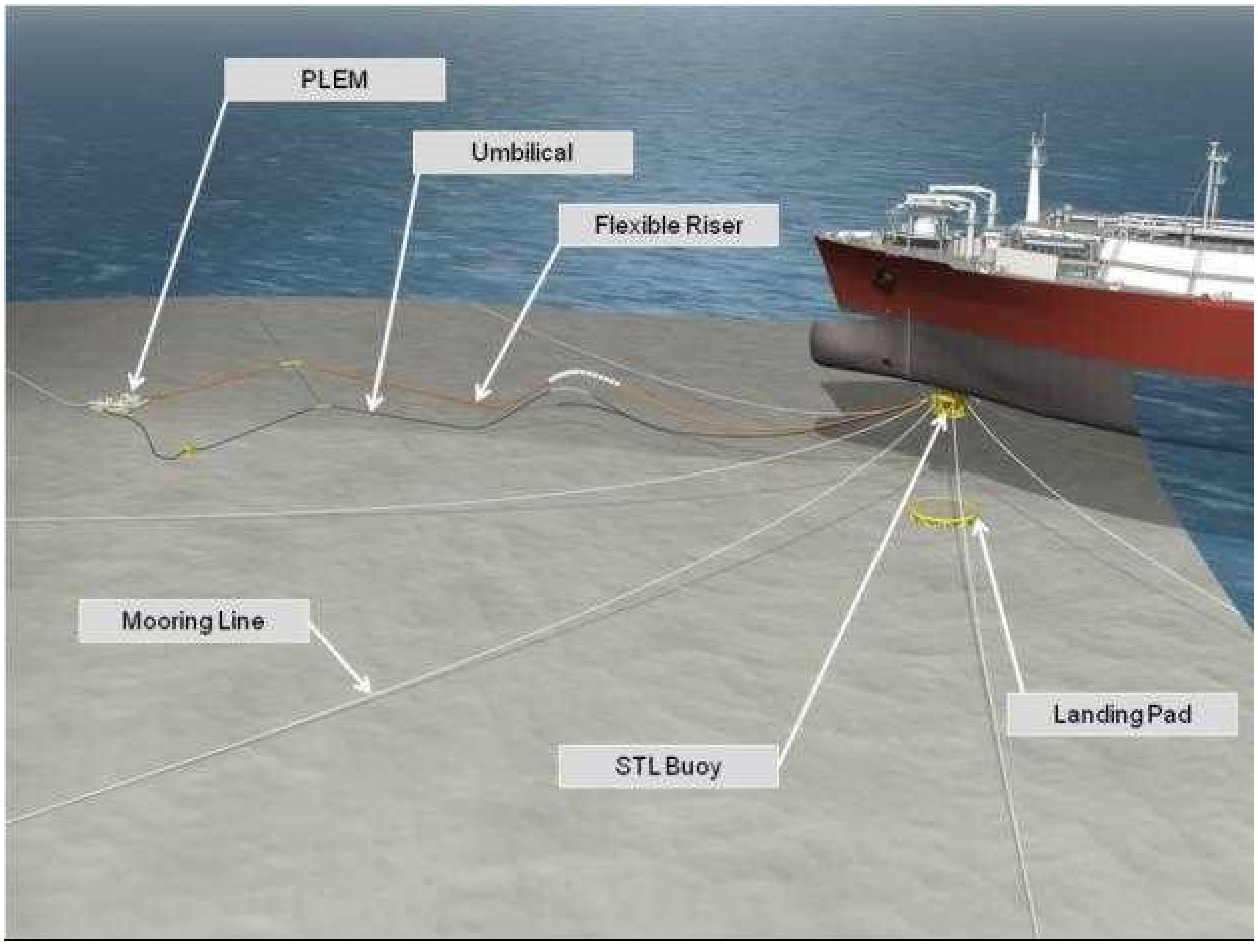
[12] Summary information on these other project is available on the MARAD website at http://www.marad.dot.gov/DWP/LNG/deepwater_ports/index.asp

The gas would be unloaded through the flexible riser into the pipeline end manifold (PLEM) for transportation to shore via the new subsea pipeline.

When the Port is not in use, the STL Buoys will be stored on the ocean floor. The exclusive use of Port Ambrose will be the off-loading and delivery of natural gas.

This proposed system for the Port Ambrose project is not capable of natural gas or LNG exports.

Figure 3-1: DWP – STL Illustration



3.1.3 Additional Project Vessels

There will be no bunkering of LNGRVs at the Port, so no vessels will be needed for that purpose. Similarly, there will be no natural gas export operations; therefore, no liquefaction vessels will operate at the port.

LNGRVs will rely upon a dedicated Support Vessel for monitoring and control purposes, as well as periodic supply and personnel transfers. This vessel will be an ocean class towing vessel of up to 130 feet (40 meters) in length, a Bollard pull (Ahead/Astern) of approximately 75 metric tons, and a draft of roughly 23 feet (7 m), and will be powered by diesel engines with up to a total of 5,000 horsepower.

It will be staffed by a crew of four to six. The Support Vessel will be equipped with firefighting capability up to DNV's FiFi1 requirements.

The Support Vessel will conduct weekly inspections of surface components of the Port. The Support Vessel will make approximately one trip per LNGRV arrival from a base of operation on the mainland.

3.2 Local Population and the Economy

If the proposed project were to impact the local economy it would most likely impact the fishing and marine tourism. The closest commercial fishing ports are Montauk and Hampton Bays-Shinnecock, New York and Long Beach-Barnegat and Point Pleasant, New Jersey. Montauk and Hampton Bays-Shinnecock are in Suffolk County New York while Long Beach-Barnegat and Point Pleasant are in Ocean County New Jersey.

In 2000 the population of Suffolk County, NY was 1,419,369 which was a 6.9% increase from the 1990 population of 1,321,864.[13] The 2012 population was 1,499,273, a 2.1% increase from 2000. The 2012 population of Ocean County, NJ was 575,961 which was a 12.7% increase from the 2000 population of 510,916. The 2000 population represented a 15.2% growth from the 1990 level of 433,203.

In 2012, total employment in Suffolk County, NY was 727,777 with 0.3% associated with the agriculture, forestry, fishing, hunting and mining category, which is lower than the New York State percentage for this category which was 0.6%. The largest employment sector for Suffolk County, NY was the education, health, and social services sector which employed 25.4% of the labor force. Unemployment in Suffolk County, NY in 2012 was 7.6% which was lower than the State of New York rate of 8.7%.[14]

In 2012, the total employment in Ocean County, NJ was 242,575 with 862 in the agriculture, forestry, fishing, hunting and mining category (0.4%). The New Jersey State percentage for this category is 0.3%. For Ocean County the largest employment sector is also education, health, and social services sector which employed 25.2% of the labor force. Unemployment in Ocean County, NJ in 2012 was 6.0% which was slightly lower than the average State of New Jersey rate of 6.3.[14]

3.2.1 Industrial Ports and Shipping

The Port Authority of New York and New Jersey has a number of marine terminal facilities. It has three cruise terminals (Manhattan, Brooklyn and Cape Liberty) and addresses a wide range of cargo including containers, autos, liquid and dry bulk, break bulk and specialized project cargo.

A 2011 study by A. Strauss-Wieder, Inc. on the economic impact of the New York New Jersey Port Maritime Industry found that in 2010, the industry supported 170,770 jobs, 11.6 billion in personal income and 37.1 billion in business income.[15]

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[13] 2007-2011 American Community Survey 5-Year Estimates.
[14] U.S. Bureau of Labor Statistics, 2012.
[15] http://www.panynj.gov/about/pdf/port-economic-impact-2011.pdf

3.2.2 Existing Activities near the Proposed Project Area

The project area is part of a busy shipping zone (Figure 3-2). While the distance from shore discourages casual boating and fishing, this leaves charter boats, cruises and commercial fishermen to utilize.

Marine traffic includes all vessels, commercial, and/or recreational, that use:

- Inbound/outbound traffic lanes of the Port of New York and New Jersey;
- Channels and navigable waterways within the New York Vessel Traffic Service (VTS) area;
- Open waters offshore the New York VTS area, where jurisdiction of the U.S. Coast Guard (USCG); and
- Hudson River, Port of Albany, and other smaller ports along the Hudson River.

Within the Port of New York and New Jersey, marine traffic is composed of a variety of vessels engaged in commercial, recreational, federal, and state functions. For this Project, the affected environment for marine transportation includes those offshore components that could be directly or indirectly impacted during construction and/or operations and by movement of LNGRVs and the Support Vessel. These areas include the New York Harbor channel system and the Traffic Separation Scheme (TSS) shipping lanes, as well as inshore marine terminals and other shoreline facilities. The following sections describe the existing marine traffic environment.

3.2.3 Commercial Fishing

The proposed site is located at least 10 nm from identified commercial fishing grounds within the area, including Cholera Bank, Middle Ground, Angler Bank, Mussel Ridge, Atlantic Beach Reef and Hampstead Town Reef. Vessels departing from Long Beach, Barnegat and Port Pleasant ports would most likely to cross through the DWP Project area due to their location in relation to the Project area. In 2011, 354 vessels in New York and 506 vessels in New Jersey had permits on record with National Oceanographic & Atmospheric Administration (NOAA) Fisheries. A total of 4,731 were on record with NOAA for the northeast in 2011.

In 2007 New Jersey and New York ranked 9th and 15th respectively out of the 48 continental states in the total volume of commercial fish landings.[16] This represented 4% and 1% of the total volume of landings in the states. In terms of value, New Jersey ranked 6th with 6% and New York 14th with 2% of all landing value.[17] In 2007 the New Jersey landings were almost 154 million pounds (70 thousand metric tons) valued at $127 million. That same year the New York landings were almost 36 million pounds (17 thousand metric tons) valued at $49 million.

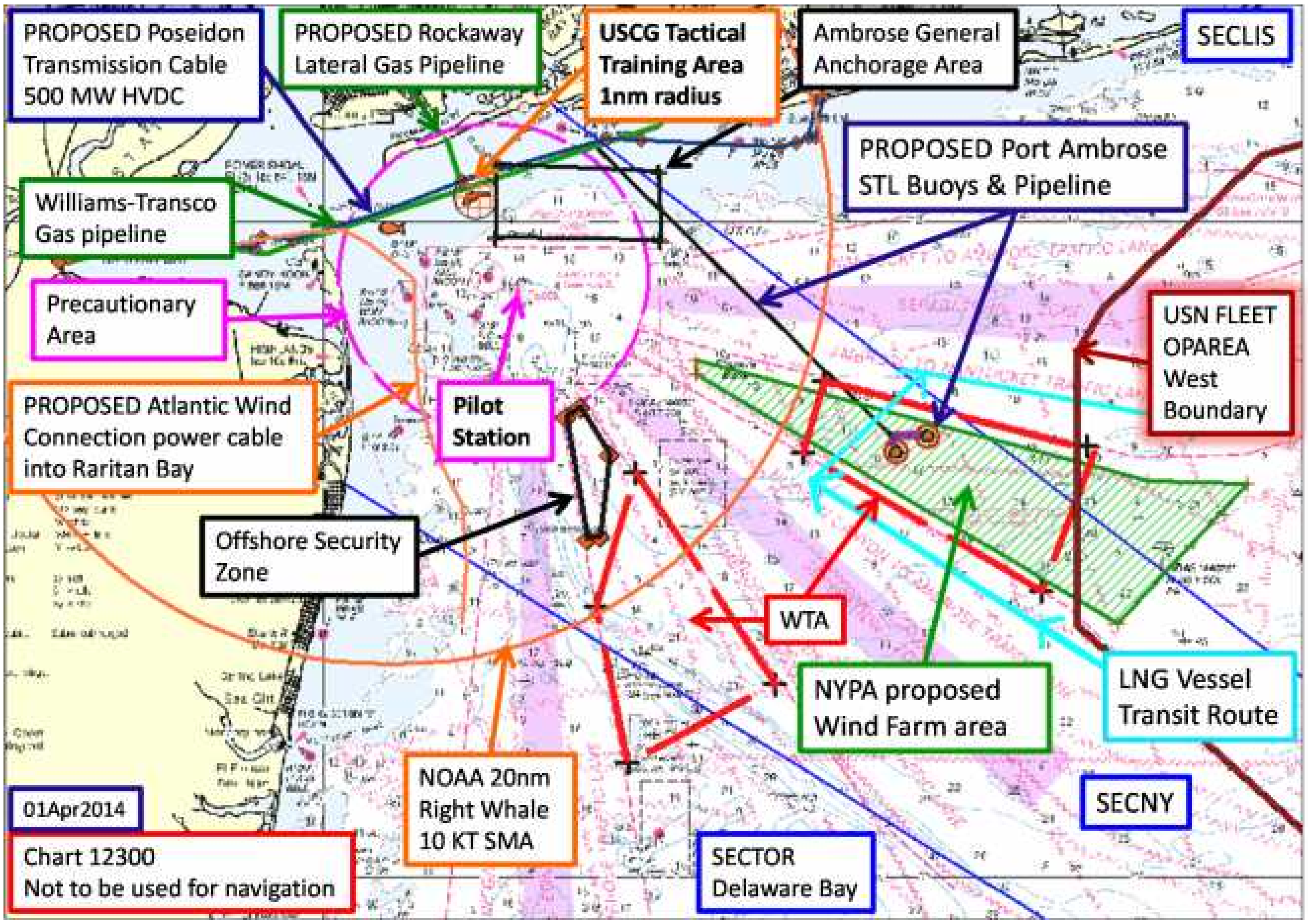
The 2011 commercial landings at Hampton Bay-Shinnecock and Montauk, the two closest ports in New York to the proposed DWP site, totaled approximately 19.3 million pounds (8.8 thousand metric tons) for a total value of $26.2 million. The two closest ports in New Jersey, Point Pleasant and Long

[16] A landing are those fish and shellfish that are landed and sold in the 50 states.
[17] National Marine Fisheries Service (NMFS), 2007.

Beach-Barnegat, had combined total landings of 24.2 million pounds (11.0 thousand metric tons) for a total value of approximately $60.6 million.[18]

The charter season typically runs from mid-March to mid-November and both inshore and offshore areas (artificial reefs and wrecks) are fished. National Maritime Fisheries Service (NMFS) tracks commercial trip data by individual statistical areas. The proposed Port is located in Regional Statistic Area 612, Blocks 44 and 45. A total of 860 commercial fishing trips were made to Blocks 44 and 45 in 2008, but the vast majority of these trips made were made outside of the proposed DWP location.

Figure 3-2: Port Ambrose Proposed Project Location



3.2.4 Recreational Boating and Water-Based Tourism

Recreational boats include runabouts, yachts, small charters, and sail boats. These vessels can be launched or are docked at shore-based facilities along the New York coastline. Vessel draft and length are restricted based on marina and channel depth limitations.

[18] NOAA Fisheries - Total Commercial Fishery Landings at Major U.S. Ports Summarized By Year and Ranked By Dollar Value (2011)

Boats under 26 ft (8 m) in length are particularly likely to be transported by trailer and will frequent launching facilities whereas larger vessels will use marinas. Due to draft limitations associated with the controlling depths of surrounding channels, inshore marinas primarily accommodate shallow draft recreational vessels with drafts ranging between 3 and 6 ft (1 and 2 m).

It is anticipated that vessels located in Kings, Queens and Richmond Counties, New York and Middlesex, Monmouth, and Ocean Counties, New Jersey could travel to the proposed Project area. Table 3-2 details the number of boats registered in Kings, Queens Counties, New York according to the 2010 New York State Recreational Boating Report and the 2008 Recreation Boating in New Jersey: An Economic Analysis Report. Offshore access to the proposed site is limited by draft and the limited number of access channels through East Rockaway, Rockaway, and Jones Inlets along the barrier island. Using New York City Department of Parks and Recreation (2010) data, nine boat launching facilities were identified.

Table 3-2: Registered Boats in Kings, Queens and Richmond Counties, New York and Middlesex, Monmouth and Ocean Counties, New Jersey

COUNTY	NUMBER OF REGISTERED BOATS
Kings County, New York[19]	4,378
Queens County, New York[18]	6,991
Richmond County, New York[18]	3,994
Middlesex County, New Jersey[20]	10,171
Monmouth County, New Jersey[19]	17,710
Ocean County, New Jersey[19]	28,231

It should be further noted that recreational vessel traffic inshore southern Long Island and offshore Long Island is seasonally variable. Vessels are more frequent in the warmer months between May and October and are concentrated within the various inlets, New York state waters, or around submerged structures and artificial reefs offshore. These vessels are relatively small, averaging between 21 and 35ft (7 and 11 m).

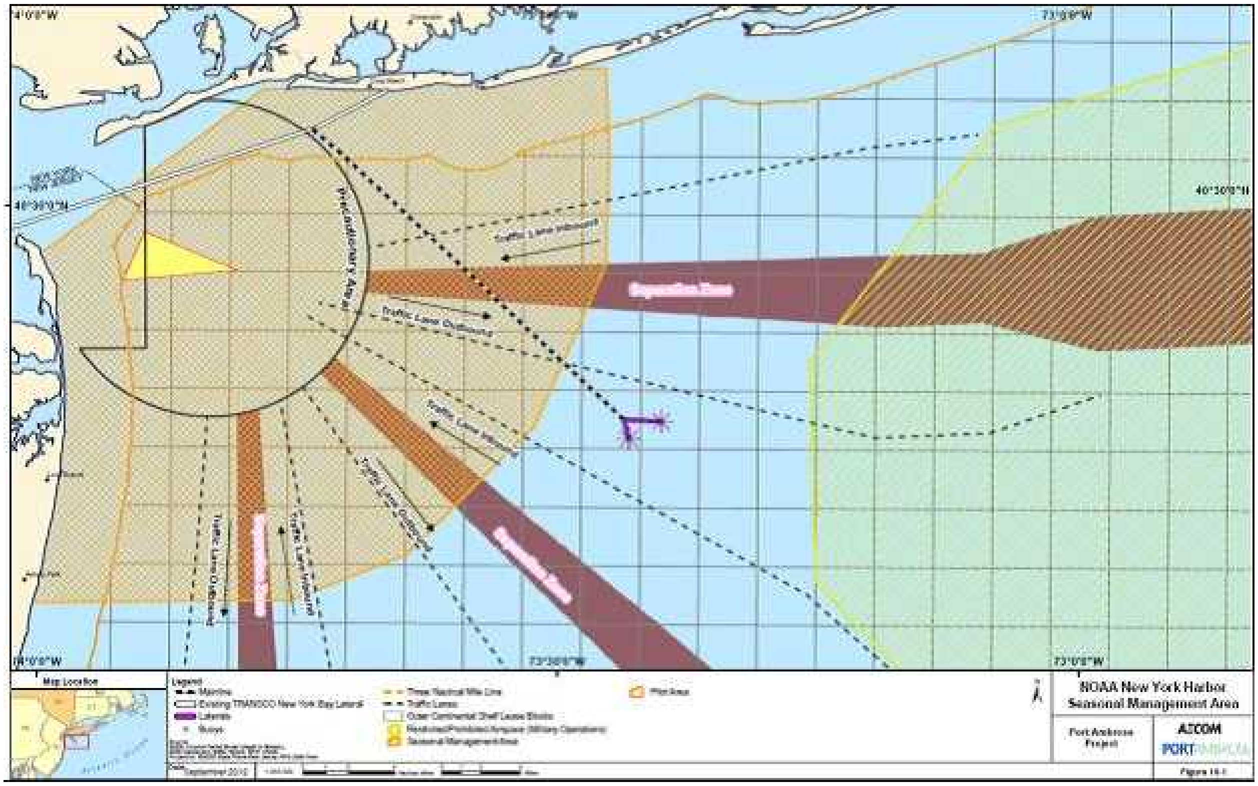
3.3 Marine Traffic Management

TSSs have been established in the approaches to New York Harbor from the sea to increase the safety of navigation (Figure 3-3). These include the eastern approach of Ambrose to Nantucket/Nantucket to Ambrose TSS, the centrally located Hudson Canyon to Ambrose/Ambrose to Hudson Canyon TSS, and the southern approach of Barnegat to Ambrose/Ambrose to Barnegat Port Ambrose Project TSS. TSSs or traffic/shipping lanes are designed to provide safer passage of vessels in converging areas of high traffic density.

Of the six aforementioned traffic lanes, the Hudson Canyon to Ambrose Inbound Traffic Lane is located west and the Ambrose to Nantucket Outbound Traffic Lane is located east north-east of the proposed mooring locations. The remaining shipping lanes are located farther outside of the proposed STL Buoy locations and are not considered to be of consequence.

[19] New York State 2010 Recreational Boating Report
[20] 2008 Recreation Boating in New Jersey: An Economic Analysis

Figure 3-3: Port Ambrose Proposed Project Location



3.3.1 Safety and Security Zones

As stated in 33 CFR Part 165, Subpart C (Navigation and Navigable Waters), "a Safety Zone is a water area, shore area, or water and shore area to which, for safety or environmental purposes, access is limited to authorized persons, vehicles, or vessels. The Deepwater Port Act directs that a safety zone be established around and including any deepwater port for the purpose of navigational safety. 33 CFR Part 150, Subpart G, authorizes the Coast Guard to establish a deepwater port safety zone. When an LNGRV is moored at Port Ambrose, it would be protected by a safety zone, extending 500 meters in all directions from the outermost portion of the hull of the LNGRV (i.e., stern) as it weathervanes on the buoy.

There are no existing safety zones charted on or adjacent to the proposed STL Buoy locations. However, there are security zones (33 CFR 165.169) surrounding bridge piers and abutments and JFK Airport within Jamaica Bay, the offshore Approaches to New York, Atlantic Ocean security zone that are within 25 nm of the two STL buoys. There are also security zones surrounding liquefied hazardous gas (LHG) vessels, cruise ships, and other designated vessels that would transit within 25 nm of the Port Ambrose project

Established under the authority of 50 U.S.C. 191 and 33 CFR 6.04-6, Security Zones are "all areas of land, water, or land and water, which are so designated by the Captain of the Port (COTP) for such time as is deemed necessary to prevent damage or injury to any vessel or waterfront facility, to safeguard ports, harbors, territories, or waters of the United States or to secure the observance of the rights and obligations of the United States." Coast Guard authority to establish security zones is applicable only to waters subject to the jurisdiction of the United States, including the territorial sea to a seaward limit of not more than 12 nautical miles. As Port Ambrose is proposed to be located outside of this limit, no security zones will be established. There are no existing security zones within 25 nm (40 km) of the Project.

3.3.2 Anchorages and Special Anchorage Areas

A Special Anchorage Area, set forth in 33 CFR 110.1, is an area where vessels of less than 20 meters in length, and barges, canal boats, scows, or other nondescript craft, are not required to sound signals required by rule 35 of the Inland Navigation Rules (33 U.S.C. 2035). Vessels of less than 20 meters are not required to exhibit anchor lights or shapes required by rule 30 of the Inland Navigation Rules (33 U.S.C. 2930). There are no Special Anchorage Areas located near the Project site.

The extent of a No Anchoring Area (NAA) proposed for the Port Ambrose Project is to avoid entanglement by any vessel's anchors and the mooring lines and anchors for the STL buoys and the pipeline. The NAA for the buoy site is proposed by the Applicant to be an area defined by the outer bounds of each STL buoy anchor system, with a radius of 1000 meters.

3.3.3 Area to Be Avoided (ATBA)

The ATBA proposed by the Applicant is proposed to have the same shape as for the NAA for the buoy site, with a radius of approximately 1000 meters from each buoy. This ATBA would help to ensure that other vessels do not interfere with the DWP operations, including maneuvering of LNG carriers and support vessels. The actual size of the ATBA would be determined, in consultation with the USCG Navigation and Standards Branch with input from the Captain of the Port. Upon its approval from IMO, the ATBA would appear on subsequent nautical charts after chart corrections are published in the Local Notice to Mariners. The ATBA is recommendatory and is meant to discourage vessel traffic in the area.

3.4 Marine Traffic Data

The following issues related to marine traffic in the project area were considered and examined in this risk assessment as they constitute a possible impact to the public in or near the project area:

- Potential increased vessel traffic (traffic associated with the proposed DWP in the area surrounding the Port of New York and New Jersey)
- Potential impact of safety zones and areas to be avoided by vessel traffic around the Port Ambrose DWP
- Potential interference with use and access to current fishing areas and other mariners and vessels transiting areas around the DWP
- Potential for collision between ships entering or departing Port of New York and New Jersey with the LNGRVs calling at the proposed DWP location

3.4.1 Commercial Shipping Traffic

U.S. Coast Guard (USCG) R&D Center, provided vessel traffic data around the area of interest around this proposed DWP (the AIS study area is highlighted on Figure 3-2). The Automatic Identification System (AIS) provided a one-year data set from October of 2011 to September of 2012 and includes these types of vessels:

- Passenger
- Cargo
- Tanker
- Other Vessels

Table 3-3: Annual Shipping Movements (October 2011 – July 2012 AIS Data covering an area bounded by Latitude 40° 10' to 40° 30' North and Longitude 73° 10' to 73° 40')

VESSEL TYPE	NUMBER OF VESSEL MOVEMENTS
Passenger	152
Cargo	2,131
Tanker	1,134
Other Vessels (including unknown)	258
TOTAL	**3,675**

In addition to vessel types and counts, the AIS data also included:

- Displacement
- Speed
- Kinetic Energy

This AIS data set was used to determine the bounding vessel collision breach size for the LNGRV and was used as input to the vessel collision frequency analysis. In these analyses, the number of vessels has been limited to those with sufficient size (displacement) and speed to potentially breach the inner hull of a LNGRV in a vessel collision, resulting in a release of LNG.

Table 3-4 details the range of displacement, average speed, and absorbed energy for the subset of vessels identified from the AIS data with the potential to breach the inner hull of a LNGRV.

Table 3-4: Vessel Type Impact Energy

Vessel Type	Displacement (tonnes)	Average Cruising Speed (knots)	Kinetic Energy (N-m)
Passenger	84 – 127,738	18.3	$6.49 \times 10^{5} – 1.11 \times 10^{10}$
Cargo	2,379 – 169,153	18.5	$2.97 \times 10^{7} – 1.24 \times 10^{10}$
Tanker	1,744 – 183,141	13.4	$1.51 \times 10^{5} – 4.93 \times 10^{9}$
Other vessel	24 – 188,166	10.3	$4.85 \times 10^{5} – 5.29 \times 10^{9}$

It is noted that the AIS dataset that does not account for seasonal or any other variations in traffic.

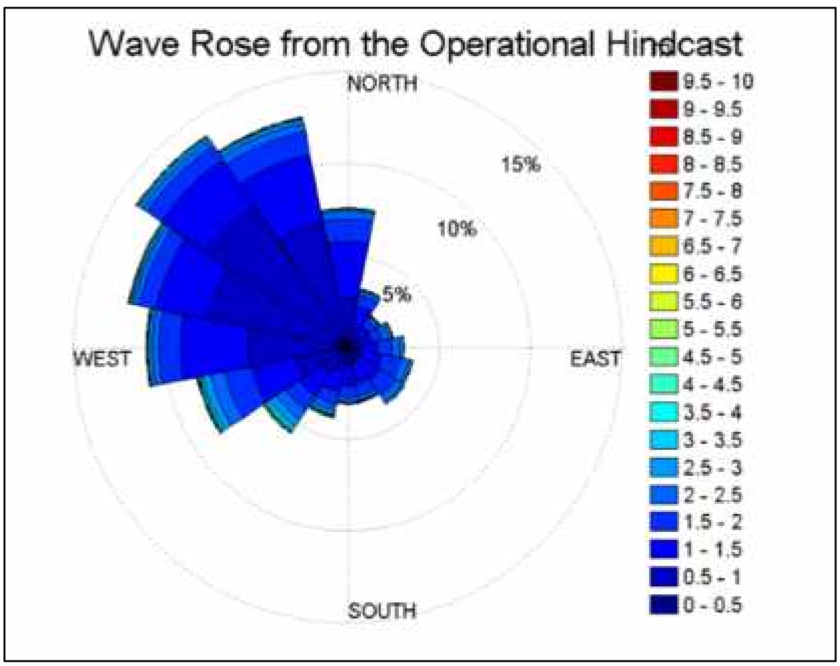
This vessel data has been applied in the breach size calculations in this Section 5, as well as the vessel collision frequency analysis in Section 6.

3.5 Weather at DWP Location

Winds, waves and tides are important when considering the risk associated at the DWP site. The Port Ambrose application contains metocean data for the project location. The follow is a summary of this information.

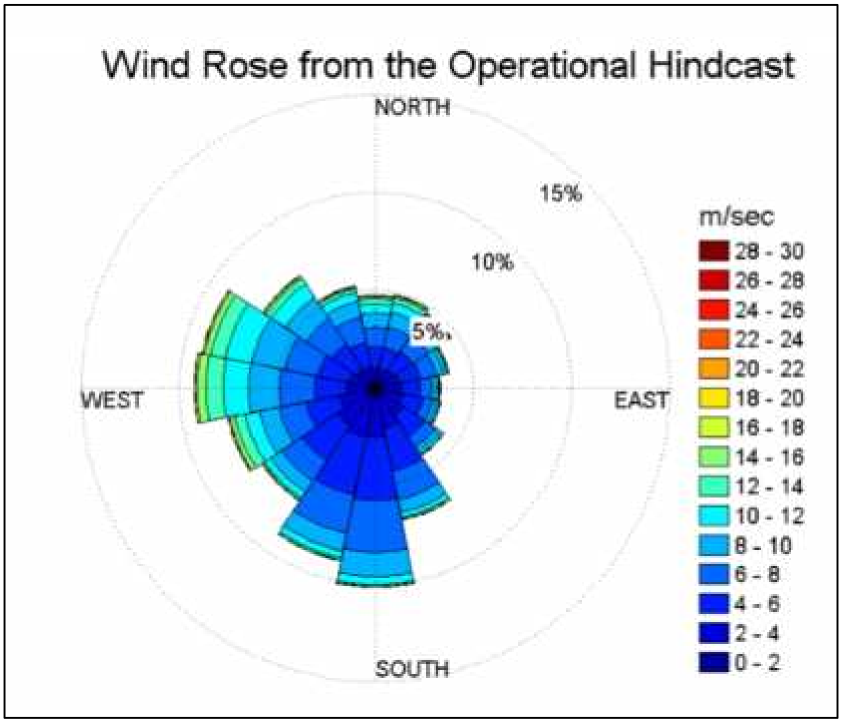
The wave height and period data was developed from the continuous Oceanweather hindcasts
A wave rose of the data is shown in Figure 3-4, and is in the direction toward which the waves are traveling. The predominate wave direction is to the northwest.

Figure 3-4: Wave Rose from Operational Hindcast for Project Location



The wind speed and direction was also developed from the continuous Oceanweather hindcasts. The data shows the percentage of the time that the specified wind speed and direction occurred during the operational hindcast. A wind rose of the data is shown in Figure 3-5. The winds are predominantly from the south.

Figure 3-5: Wind Rose from Operational Hindcast for Project Location



The current speed and direction data was developed from the Rutgers CODAR measurements. A current rose of the data is shown in Figures 3-6. Currents in all directions are equally likely.

Figure 3-6: Current Rose from CODAR for Project Location

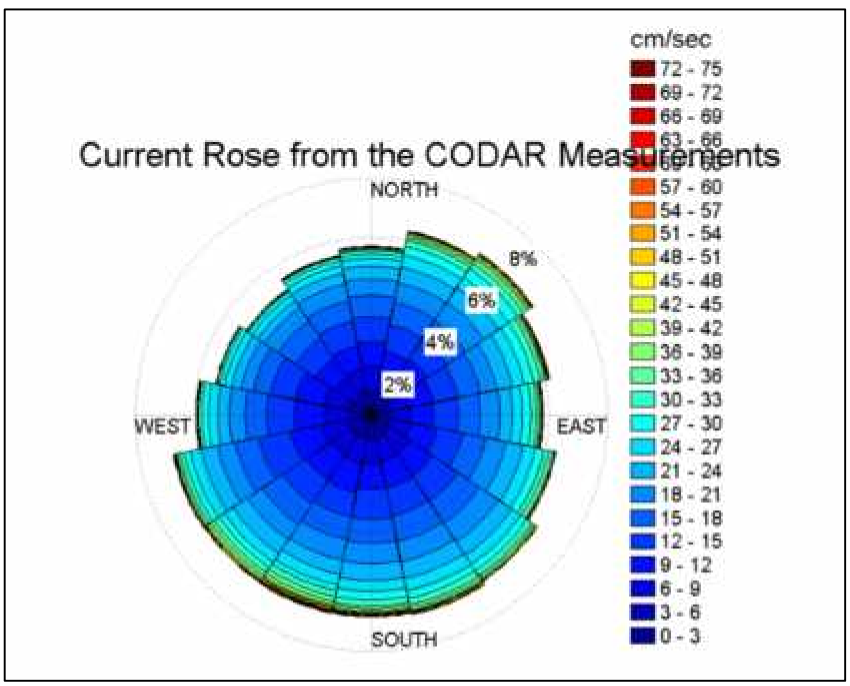


Table 3-5 details the Metocean data for the proposed Safe Harbor Energy DWP site.

Table 3-5: Metocean Data for the Proposed Port Ambrose Project Location

Parameter	Value
100 Year Wind Speed	33.27 m/s
100 Year Significant Wave Height	8.54 m
Maximum Measured Surface Current	87.5 cm/s

The LNGRVs will monitor current and forecasted weather conditions through regular monitoring of the vessel's equipment (such as radar, barometer, anemometer, and visual observation from the bridge) as well as monitoring National Weather Service internet and VHF voice broadcasts of current and forecasted marine conditions, Dial-A-Buoy service from Station 44065-Entrance to NY Harbor, real-time weather radar satellite imagery via internet, and mass media weather broadcasts available by satellite on the vessel's TV system.

The Port Manager and LNGRV Master at the first sign of significant weather will determine the Master's needs and plans for storm evasion, such that any order to evacuate will be done in a manner timely enough to allow safe weather evasion. Evacuation due to forecasted weather in excess of the limits below will be ordered by the Port Manager in consultation with the LNGRV Master, and in accordance with the COTP New York Hurricane and Severe Weather Plan. Proper notifications and consultations with USCG will be made.

In addition the STL system components are designed for:

- LNGRV to stay connected in the 10-year storm condition
- Idle system will survive the 100-year storm condition

Severe weather was considered in both in the Port Ambrose DWP application and during the HAZID process, described in Section 4.0. Due to the relatively predictable weather around the port, combined with the robust ship and equipment design, procedures to predict adverse weather conditions, and the ability to disconnect from the buoy should severe weather develop suddenly during transfer operations,[21] significant damage to an LNGRV or the DWP due to severe weather is considered unlikely.

3.6 Proposed Wind Energy Area

The proposed Port Ambrose falls within the proposed area of interest for the wind energy project(s) proposed for offshore New York as described in the Bureau of Ocean Energy Management's Call for Information of May 28, 2014 (79 FR 30645). The risk assessment will take this proposal into account; however, because of the lack of wind energy specific project details, this report is necessarily constrained in its ability to provide an analysis of the navigational safety risks that operation of the deepwater port may have on a future wind farm siting and operation. While it would be inappropriate for this report to purport to establish specific setbacks between the deepwater port, vessels operating in

[21] Port Ambrose Application, Vol. III, Sec. 9 (Draft Operations Manual) (Confidential).

the area, and the wind farm, this report does provide information on LNG spill consequences which will help inform any future offshore wind energy project proponent on future siting of wind turbines.

The operation of the port will incorporate a number of risk mitigation measures which may serve to lessen the risk of adverse consequences between the deepwater port's operation and the construction and operation of a wind farm. These measures include, but are not limited to: the stationing of tug assist at the port prior to an LNGRV arriving which will be available to render immediate assistance in the event of a marine casualty (e.g., loss of propulsion or steering), measures that restrict port operations if certain wind and sea state conditions are exceeded, and other emergency procedures contained in the port Operations Manual. To the extent practicable, in the absence of a detailed wind farm application, the Phase II portion of the IRA will examine navigational safety concerns and consider applicable measures that may serve to mitigate potential risks of both facilities operating in the same geographic area.[22]

[22] This IRA does not establish enforceable requirements on any potential future wind farm operator. The BOEM may consider this information as it determines what, if any, operational restrictions may need to be imposed on a proposed wind farm. Pursuant to the Memorandum of Agreement between (then) BOEMRE and the USCG (dtd 27Jul2011), the USCG will assist BOEM in assessing the navigational risks that may be posed by renewable energy development projects, For additional information, see Navigation and Vessel Information Circular, 02-2007, "Guidance on the Coast Guard's Roles & Responsibilities for Offshore Renewable Energy Installations (OREI)."

4.0 Hazard Identification (HAZID) Study

The HAZID was a comprehensive review of the applicant's proposed DWP operation, including operation of the Shuttle & Regasification Vessels (LNGRV) and offloading at the buoys. The purpose of the HAZID is to develop and review credible accidental and intentional events (scenarios) that could potentially impact the public, and that will be analyzed throughout the Independent Risk Assessment (IRA) process.

The HAZID workshop was conducted on January 16-17, 2014, at the Maher Terminal Training Room in Elizabeth, New Jersey. AcuTech facilitated the meeting and the HAZID team included representatives from U.S. Coast Guard (USCG) Sector NY, USCG CG-OES-4, Sandia National Laboratories, Port Authority of New York and New Jersey and USCG, federal, state and local emergency responders, law enforcement intelligence, and pilots listed in Table 4-1.

The first day of the HAZID workshop included the applicant's overview presentation of the proposed Port Ambrose project to the HAZID team. This presentation from Liberty Natural Gas, LLC included an overall project familiarization including the regasification and transfer process, ship traffic data, meteorological conditions, and information on the LNGRVs. Following the presentation, the applicant was excused and the HAZID team utilized the remaining time to evaluate potential events that could impact the DWP and its operations and in-turn cause negative impact to the public.

4.1 HAZID Process

The focus of this IRA is potential impact to the public. Therefore during the HAZID process worst but credible accidental and intentional scenarios involving the Port Ambrose Deepwater Port (DWP) were considered. The most prevalent material located at the DWP which could produce consequences of a negative nature is the large amounts of LNG in the carriers. Therefore, the emphasis of the HAZID was on the identification of events that could lead to large releases of LNG and potentially impact populations including those onshore, and on private or commercial vessels (those not associated with the project) in the vicinity.

Because the scenarios were being defined without prior knowledge of the resulting consequence, no scenario proposed by the team was dismissed due to criteria that the final impact would be small. Also no scenario was dismissed because it was deemed to be highly unlikely to occur. If based on the experience and knowledge of the participants a scenario was deemed to be credible it was considered.

As a minimum baseline, the following scenarios were discussed and evaluated to determine their suitability for further analysis:

- Marine collision and/or allision that results in penetration of LNG cargo containment
- Mechanical or structural system failure resulting a major accidental LNG spill
- Fire resulting in cascading events leading to compromise on LNG containment
- Severe weather to include lightning, wind, waves or currents
- Dropped objects
- Direct attack using vessel or performed by a single or multiple intruders
- Standoff attack
- Sabotage

- Hazards associated with proximity to USCG operations that occur in the area
- Coexistence and hazards associated with proximity to the proposed area of interest for the wind energy project(s) proposed for offshore New York as described in the Bureau of Ocean Energy Management's Call for Information of May 28, 2014 (79 FR 30645).

The IRA focused solely on the specific maximum potential impacts to the public associated with offshore storage and regasification of LNG at the proposed DWP; therefore, processes beyond the Pipeline End Manifold (PLEM) and pipeline failures were not considered as part of the HAZID.

4.2 HAZID Scope

The Port Ambrose HAZID Workshop participants analyzed the following operational segments:

1. LNGRV in Transit to DWP
2. DWP
   - 2.1. Mooring System
     - 2.1.1. One LNGRV at DWP
     - 2.1.2. Two LNGRVs at DWP
   - 2.2. Transfer System
     - 2.2.1. Regasification Skids on LNGRV
     - 2.2.2. Submerged Turret Loading (STL) Buoy System
   - 2.3. PLEM
   - 2.4. PLEM to pipeline
   - 2.5. USCG operations that occur in the area
   - 2.6. Coexistence with wind energy project(s) proposed for offshore New York as described in the Bureau of Ocean Energy Management's Call for Information of May 28, 2014 (79 FR 30645).

The following segments were excluded from consideration:

1. LNGRV in transit to and from Port (outside of Traffic Separation Scheme (TSS))
2. Pipeline to offshore pipeline connection

4.3 Port Ambrose HAZID Workshop Attendees

Table 4-1: HAZID Participant List

Name	Comments
U.S. Coast Guard Headquarters, Deepwater Ports Standards Division, CG-OES-4	
U.S. Coast Guard Headquarters, Navigation Standards Division	
U.S. Coast Guard, Sector New York	
U S Coast Guard District One	
US Maritime Administration	
U S Bureau of Ocean Energy Management	
AcuTech Group, Inc.	
Sandia National Lab.	
New York Office of Homeland Security	
New York State – Dept. of State	
New York State – Dept. of Environmental Conservation	
New York Power Authority	
New Jersey – Dept. of State	
New York City – Office of Emergency Management	
New York City Fire Department	
New York City Police Department	
New York New Jersey Port Authority	
Sandy Hook Pilots	
Maritime Association of the Port of New York New Jersey Tug & Barge Subcommittee	
Liberty Natural Gas LLC	Applicant present 09:00-12:30 on day one and available to respond to technical queries for the remainder of the HAZID.

5.0 Scenario Development

Following the HAZard IDentification (HAZID), the identified scenarios were further reviewed and a subset was selected for further development in the risk assessment. A copy of the HAZID results was submitted to the U.S. Coast Guard (USCG), but is not appended here as it contains information pertaining to intentional acts, which has a homeland security concern. While the full HAZID is not presented, the key findings have been carried through this section.

A subset, as opposed to a full range of accidental and intentional scenarios, was analyzed in this risk assessment since the purpose of this analysis is to identify the results of the bounding credible worst-case release scenarios. The process that the USCG requires for the evaluation of a LNG Deepwater Port (DWP) project application is comprised of two phases: Phase I of the IRA evaluates the worst credible accidental and intentional scenarios; Phase II of the Independent Risk Assessment (IRA) will evaluate the full range of all possible releases to develop the safety and security strategy for the security and operations manuals. Phase II also discusses various mitigation measures that may be employed to reduce the risk of the identified hazards. This section discusses all of the scenarios identified during the HAZID process and presents information and analysis used to screen-out cases which were deemed not to be the bounding cases.

In addition to discussing the method that was used to select the final accidental and intentional release scenarios, this section also details the resulting consequences that were modeled (i.e., breach sizes). For the release scenarios included in the risk assessment, this is defined as an expected breach size in the inner hull of a LNG regasification vessel (LNGRV), a release from process equipment, or any other locations or scenario where LNG could be potentially released.

Section 7 details the analysis of the consequences and the resulting thermal radiation hazard distances and flammable vapor cloud dispersion results from the intentional and accidental scenarios.

5.1 Accidental Scenario Development

The HAZID identified twelve potential accidental release scenarios that have the potential to result in a release of LNG. These accidental scenarios included:

- Scenario 1 – Vessel Collision / Allision
- Scenario 2 - Shipboard Mechanical System Failure
- Scenario 3 - Fire
- Scenario 4 - LNG Release at Process Equipment
- Scenario 5 - Severe Weather
- Scenario 6 - Structural Failure of LNG LNGRV (including the tanks)
- Scenario 7 - Grounding
- Scenario 8 – Mooring System Failure
- Scenario 9 - Aviation
- Scenario 10 – Natural Phenomena
- Scenario 11 – Dropped Objects
- Scenario 12 – Buoy Entanglement

The accidental scenarios were discussed and reviewed with the HAZID participants and evaluated based on scenario significance. Based on that review, Scenario 1 – Vessel Collision / Allision was identified as the scenario with the greatest potential of significant LNG release.

5.1.1 Marine Release

During the past 45 years, there have been approximately 100,000 LNG carrier voyages,[23] covering more than 235 million miles.[24] There is no report of any accident involving a LNG carrier underway that has resulted in an unintentional release of LNG cargo. This covers export locations (e.g., Alaska, Algeria, Trinidad, Indonesia) and various import locations (e.g., Boston, Lake Charles, Savannah, and several locations in Japan and Korea).

Many of these locations are in ports and environments more busy and complex than that of the proposed Port Ambrose DWP and present greater potential for collisions, allisions, and groundings than this location. It would be inaccurate to state that there have been no marine mishaps involving LNG carriers. Over the life of the industry, sixteen cargo transfer incidents worldwide have resulted in limited LNG spills with some damage, but no cargo fires have occurred.[25] In addition to these cargo transfer incidents, there have been collisions, groundings, loss of vessel propulsion, cargo tank leaks, vent riser fires, insulation fires, and other miscellaneous incidents involving LNG carriers, but none of these incidents have resulted in a release of LNG to the environment.

The maritime scenarios identified in the HAZID include collision/allision, mechanical failure, groundings, and other accidental and intentional acts. Even though historically there are no reported marine accidents that have resulted in a breach of containment, the vessel speeds and sizes that traverse the open waters and the vessel safety fairway near the Port Ambrose DWP location have the potential to significantly damage an LNGRV, if a collision were to occur.

The expected breach size on the inner hull of an LNGRV from a vessel collision scenario is presented in Section 5.3. Marine collision is also presented in Section 6 as part of the collision analysis to determine the frequency of a vessel collision with the LNGRV that could result in a breach of containment and loss of LNG to the environment.

The buoys for the Port Ambrose DWP project are located approximately 16.1 nautical miles away from any landmass or shallow water, reducing the chance of a grounding event. Therefore, the grounding of an LNGRV in transit to and from the buoy has not been evaluated as a bounding scenario and screened-out for further consideration.

5.1.2 Process Release

In addition to the release of LNG associated with a possible collision/allision, several other types of scenarios are possible with the LNG carriers associated with the Port Ambrose project. Since an

[23] A "voyage" is defined as both the loaded and unloaded LNG carrier movement between the loading port and discharge port.
[24] Data compiled from SIGGTO 1976-2000 and International Group of Liquefied Natural Gas Importers, *The LNG Industry* (Clichy, France: International Group of Liquefied Natural Gas Importers, 2002-2006).
[25] USCG DWP Standards Division maintains LNG accident/incident data. This data will be included as an Appendix to the DEIS/FEIS.

LNGRV has significant top-side processing equipment for the regasification of LNG and the distribution of natural gas to the subsea pipeline, there is a potential for process-related releases. These scenarios involve equipment failures, human errors, or external events (weather-related events are addressed separately) that can result in a release of LNG or natural gas leading to fires, explosions, or other serious shipboard events. Similar consequences could also be initiated intentionally via onboard sabotage.

The Applicant proposes that all project elements will integrate safety systems and equipment during all phases of the project. These systems and equipment include: hazard detection, emergency shutdown, spill containment, fire protection, flooding control, crew escape and safety shelters, and all other safe guarding systems as may be required by federal and international regulations and standards.

The Applicant states that the integrity of the regasification equipment, LNG storage, submerged turret loading (STL) buoys, and pipeline systems will be assured through a formal and documented set of operational procedures, inspections, personnel training, as well as a quality assurance audit and maintenance program. All vessels, pumps, storage tanks, instruments, piping and environmental control equipment are to be inspected and maintained to high standards which will be specified in the final design of the Port Ambrose systems and equipment. All maintenance operations will be performed under strict guidelines designed to minimize risk of releases and to ensure the safety of people and systems.

In addition to the inherent designs and high standards for operational practice, the public, contractors, Port Ambrose personnel, the LNGRVs and the DWP offshore and onshore systems will be protected by comprehensive emergency shutdown systems. Emergency shutdown comprises multiple levels of action from an individual piece of equipment, to shutdown of a system or multiple systems in an area, to an overall facility or project shutdown. The Applicant states that these shutdown systems will be high-integrity, proven technology, and will be redundant systems that can initiate a range of shutdown actions depending upon the cause and nature of the event(s) that produced the emergency condition.

The applicant further states that the safe transfer of natural gas from the LNGRV will be ensured by a series of sensors that provide feedback to the operator panel and that can automatically shutdown gas transfer. Additionally, there are a series of emergency shutdown valves that will also interrupt gas transfer in the event of an unsafe condition along with emergency buoy disconnect procedures for interrupting gas flow as well.

These systems and associated procedures are summarized below and comprise the principal means for dealing with the unsafe discharge of natural gas.

There are three shutdown levels governing the transfer of natural gas from the LNGRV to the STL Buoy:

- Automatic Shutdown (ASD)
- Emergency Shutdown (ESD)
- Emergency Buoy Disconnect (EBD)

The safety related equipment and functions associated with these shutdown levels are described as follows.

Emergency Shutdown (ESD)

ESD is controlled by automatic or manually activated systems:

- Automatic shutdown through the fire and gas detection or other systems on the LNGRV requiring a total shutdown of gas export
- Manual shutdown through ESD buttons positioned at strategic locations

Automatic or manual operation activates closed all of the three ESD valves (ESDV) which are located:

- ESDV1 – ESD valve mounted on main deck upstream of the STL Buoy system
- ESDV2 -- ESD valve mounted in the submerged turret loading (STL) Buoy
- ESDV3 – ESD valve mounted subsea in the pipeline end manifold (PLEM)

The ESD valves are operated by spring return, hydraulically powered actuators with a fail-safe spring return to the closed position. The hydraulic power for operation of the valves is supplied from the STL valve control system. The signal for indicating the open or closed position of the valves will be sent to the vessel control system.

Emergency Buoy Disconnect (EBD)

EBD can only be activated manually through the EBD button located on the STL operator panel on the LNGRVs navigation bridge. EBD involves a shutdown of the gas export operation followed by an automatic disconnection of the STL Buoy. The EBD is initiated through push-button activation in two steps. Step one disconnects the STL gas transfer system while step two releases the STL Buoy. Total time required for the vessel to complete an emergency STL buoy disconnect operation is estimated to be approximately 15 minutes.

Regulatory Vessel Design Requirements[26]

The LNGRVs are designed to be built to comply with the following rules, regulations, and requirements:

- Maritime regulations of the registered country
- International Convention for the Safety of Life at Sea (SOLAS), 1974 with Protocol of 1978, and the amendments up to 2003
- International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
- International Convention on Load Lines, 1966 with the Protocol of 1988
- International Convention for Preventing Collisions at Sea, 1972 including amendments of 1981, 1987, 1989 and 1993
- International Tele-Communications Union (ITU) Radio Regulations, 1982

[26] Port Ambrose DWP Application – Volume II, Section 11, Pgs 8-10

- International Convention for the Prevention of Pollution from Ships (MARPOL), 1973 (Annexes I, IV, V and VI (Regulation 12,13, 14 and 16)) with Protocol of 1978 and up to the latest amendments
- MEPC 53/24/Add.2 Proposed Amendments to the Revised MARPOL Annex I
- (Addition of new regulation 13A on oil fuel tank protection) International Convention on Tonnage Measurement of Ships, 1969
- International Labour Conference concerning Crew Accommodation On Board Ship, Convention No. 92 and 133 (except swimming pool)
- ILO Codes of Practice, Safety and Health in Dock Work
- International Electro-Technical Commission (IEC) Publication No. 60092 and International Electro-Technical Commission (IEC) Publication No. 60533 "Electrical and Electronic Installations in Ships-Electromagnetic Compatibility"
- Suez Canal Navigation Regulations and Tonnage Measurement of Ships
- International Convention on Standards of Training, Certification and Watchkeeping (STCW), 1993 and later amendments
- IMO Resolution A.468 (XII) "Code on Noise Levels On Board Ships", 1981
- IMO Resolution MSC137 (76) "Standards for Ship Maneuverability"
- IMO Resolution A.330 (IX) "Amendment to the Recommendation on Safe Access to and Working in Large Tanks to Include Large Water Ballast Tanks"
- IMO Resolution A601(15) Provision and Display of Maneuvering Information On Board Ships
- IMO Publication No. 978 - Performance Standard for Navigational Equipment
- U.S. Coast Guard's Regulations for Foreign Flag Vessels Operating in Navigable Waters of the United States (except Alaskan waters, without Certificate or Inspection)
- 33 CFR Part 155: Oil Pollution Prevention Regulations for Vessels
- 33 CFR Part 156: Oil and Hazardous Material Transfer Operations
- 33 CFR Part 159: Marine Sanitation Devices
- 33 CFR Part 164: Navigation Safety Regulation

In addition, the LNGRVs may be subject to the following recommendations and guidelines, as applicable:

- ISO 6954-2000: "Mechanical Vibration - Guideline for the Measurement, Reporting and Evaluation of Vibration with Regard to Habitability on Passenger and merchant ships"
- ISO 8309-1991: Refrigeration Light Hydrocarbon Fluids. Measurements of Liquid Levels in Tanks Containing Liquefied Gases Electric Capacitance Gauges
- U.S. Department of Labor Safety and Health Regulations for Longshoring
- Oil Companies International Marine Forum (OCIMF) "Recommendations on
- Equipment for the Towing of Disabled Tankers," 1981
- OCIMF "Mooring Equipment Guidelines," 1997
- OCIMF "Ship to Ship Transfer Guide (Liquefied Gases)," 1995
- OCIMF "Recommendations for Manifolds for Refrigerated Liquefied Natural Gas Carriers (LNG)," 1994
- Society of International Gas Tanker and Terminal Operators (SIGTTO) "Recommendations and Guidelines for Linked Ship/Shore Emergency Shutdown of Liquefied Gas Cargo Transfer," 1997

- SIGTTO "Recommendations for the Installation of Cargo Strainers on LNG Carriers," 1992
- International Chamber of Shipping (ICS) Guide to Helicopter / Ship Operations
- International Electro-Technical Commission (IEC) Publication 92
- ISO 4406: Hydraulic System Flushing
- VDI 2056 Criteria for Assessment of Mechanical Vibrations in Machines
- IMO Resolution A343(ix) Recommendation on Method of Measuring Noise Levels at Listening Posts
- ISO 8501-1, 1988 (Preparation of Steel Substrates before Application of Paints etc)

The Applicant will be required to comply with applicable codes and standards for the LNGRV safety systems and equipment onboard the vessel. These systems and equipment include: detection, emergency shutdown, spill containment, fire protection, flooding control, crew escape and safety shelters, and all other such equipment as required by applicable federal and international regulations and standards.

Like all LNG carriers, the LNGRVs (membrane and Moss design) will be double-hulled, with the interspaces continuously monitored for leaks. The ships will have cargo surveillance and electronic guidance equipment to ensure the integrity of the LNG cargo.

The LNGRVs will be designed and built under the survey of a selected Recognized Classification Society's (RCS) Rules and IMO Regulations in force at the date of the design contract signing, with the objective of obtaining an IMO Certificate of Fitness.

LNGRVs are designed to carry cryogenic gases and follow stringent International Maritime Organization (IMO) regulations that govern their construction and operation. IMO is an independent organization that provides specific rules for the construction standards for LNG carriers, including safety equipment, marine pollution prevention, operational procedures, and crew training. The IMO conventions, codes, and resolutions that Port Ambrose will follow address the minimum acceptable requirements for such a vessel according to International and U.S. Regulations.

International Labor Organization (ILO)

- ILO Conventions Concerning Crew Accommodation on Board Ships (No. 92&133)

IMO – Conventions

- IMO 110E, International Convention for Safety of Life at sea, 1974 with protocol of 1978/1988 and current amendments (SOLAS)
- IMO 701E, International Convention on Load Lines, 1966 and protocol of 1988 and amendments up to and including the 2003 amendments and later amendments (ICLL)
- IMO 714E, International Convention on Tonnage Measurement of Ships, 1969 as amended by IMO Resolution A.493 and A.494 (XII)
- IMO 904E, Convention on the International Regulations for Prevention of Collisions at Sea (COLREGS) 1972 and later amendments, including IMO Resolution A.464 (XII)

<u>IMO – Codes</u>

- IMO 104E, "International Code For The Construction And Equipment Of Ships Carrying Liquefied Gases In Bulk", International Maritime Organization, 1993 Edition and Supplemental from 1994 and 1996 (IGC Code)
- IMO 116E, "International Ship and Port Facility Safety Code," International Maritime Organization, 2003 Edition (ISPS Code)
- IMO 117E (A), "International Safety Management Code & Revised Guidelines on Implementation of the ISM Code," International Maritime Organization, 2002 Edition (ISM Code)
- IMO 155E, "Fire Safety Systems (FSS) Code," International Maritime Organization, 2001 Edition
- IMO 520E, International Code for Safe Management of Ships and for Pollution from Ships, 1973 (Annex I, IV, V and VI), as modified by the Protocol of 1978 relating thereto and later amendments (MARPOL 73/78)
- IMO 978E, Performance Standards for Navigational Equipment (1997)
- IMO 982E (C), "Life-Saving Appliances," International Maritime Organization, 2002 Edition International Telecommunications Union Radio Regulations 2001 and SOLAS Chapter IV, as amended International Convention on Tonnage Measurement of Ships 1969 as amended by IMO Resolutions and later amendments

<u>IMO – Resolutions</u>

- IMO Resolution A272/A330 "Safe Access to and Working in Large Cargo Tanks and Ballast Spaces"
- IMO Resolution A.343 (IX) "Recommendation on Methods of Measuring Noise Levels at Listening Posts"
- IMO Resolution A.468 (XII) "Code on Noise Levels Onboard Ships"
- IMO Resolution A601 (15) "Provision and Display of Maneuvering Information Onboard Ships"
- IMO Resolution A.686 (17) "Code on Alarms and Indicators"
- IMO Resolution A.708 (17) "Navigation Bridge Visibility and Functions"
- IMO Resolution A719 (17) "Prevention of Air Pollution on Ships"
- IMO Resolution A751 (18) "Interim Standards for Ship Maneuverability"

Compliance with these regulations minimizes the likelihood of an accidental LNG release at the proposed DWP project. Additionally, these safety features would also mitigate any release, regardless of cause. The safety features of the LNGRV for this project are summarized below:

- **Double-Hull Construction**. The IMO/IGC requires LNG carriers to be constructed with an outer and inner hull to provide protection against collisions or groundings and resultant cargo loss. These hulls would be separated from each other by structural members and separated from the cargo by the membrane system. Thus, a collision, grounding, or other impact would need to penetrate up to four layers to result in cargo spillage.

- **Separation of Cargo Holds and Piping Systems**. The IGC requires the structural separation of cargo holds from other spaces as well as separation of cargo piping from other piping systems. This helps keep cargo leaks away from potential ignition sources and keeps cargo from inadvertently being pumped through the wrong pipes.

- **Accessibility for Inspection Access**. The IGC requires that a tank be constructed so that at least one side is visible and accessible to inspectors. This allows proper periodic inspection of the tank for integrity and signs of corrosion or stress.

- **Leak Detectors in Hold Spaces**. The IGC requires that gas detectors and low temperature sensors be placed in a cargo hold in order to detect cargo leakage. An alarm sounds if either is detected and appropriate precautions and mitigation repairs can be made.

- **Tank Requirements for Cargo Containment**. The IGC requires that a tank be constructed with materials that can withstand the temperatures involved so as to properly contain the cargo and have adequate relief valve systems to avoid over pressurization.

- **Structural Analysis**. The IGC requires structural analysis of the cargo containment system and specifies individual tank stress limitations.

- **Secondary Containment and Thermal Management**. The IGC requires partial secondary containment to contain leaks and prevent contact of cryogenic liquid with the inner hull. This prevents thermal stress. In addition, insulation in conjunction with a primary and backup heating system must be installed that would keep the cargo from exceeding the thermal limitations of the material selected for the inner hull if the leak prevention system should fail.

- **Tank Construction and Testing Requirements**. The IGC addresses standards for workmanship, quality, and testing of tanks under construction. Before cargo is pumped aboard, each tank on the LNG carriers would have had its welds nondestructively tested and a pressure test would have been performed to ensure integrity.

- **Isolation, Construction and Testing Requirements for Piping and Pressure Vessels**. The IGC specifies piping thickness, leak testing, pressure testing, isolation requirements, welding requirements, and many other aspects of pressure vessel and piping design and construction. This ensures the integrity of these systems before any cargo is brought aboard.

- **Emergency Shutdown Valves and Shutdown Systems**. The IGC requires remote-control shutdown systems for shutting down cargo and vapor transfer in an emergency. This system must have the ability to be activated from at least two locations on board the LNG carrier and would also be automatically activated in the event of a cargo fire.

- **Pressure Venting Systems**. The IGC specifies that appropriate venting of the cargo be installed to keep the cargo under the design pressure of the tank and keep relief valves from needing to operate

- **Vacuum Protection Systems**. The IGC requires the installation of relief valves that would prevent under-pressurization of cargo tanks in the event that cargo was pumped out without adequately providing for vapor return. The LNG carrier would have sufficient vapor return capacity to keep the pressures at appropriate levels; however, this system would prevent under-pressurization if this system should fail to be actuated or fail to work properly.

- **Fire Protection Systems**. The IGC requires that LNG carriers have a saltwater fire-main system for fighting fires throughout the ship and fixed dry chemical and carbon dioxide systems for cargo areas and compressor rooms, respectively.

- **Water-spray System.** The IGC requires that ships carrying flammable or toxic products or both install a water-spray system for cooling, fire prevention and crew protection to cover exposed cargo tank domes and any exposed parts of cargo tanks; exposed on-deck storage vessels for flammable or toxic products; cargo liquid and vapor discharge and loading manifolds and other areas where control valves are situated; boundaries of superstructures and deckhouses that are normally manned, and other high fire risk items and cargo control rooms.

- **Cargo Tank Instrumentation**. The IGC requires that each cargo tank be outfitted with an integrated instrumentation/alarm system that notifies the crew of possible leaks via gas detection and temperature sensors and tank liquid levels, temperatures, and pressures. These systems, as well as the pressure relief systems mentioned above, provide a many-layered protection against cargo release either through equipment malfunction or human error.

- **Additional Gas Detection Systems**. The IGC requires gas detection systems and alarms in spaces where cargo is located, including compressor spaces, spaces where fuel gas is located, and other spaces likely to contain gasified cargo. Venting systems for certain spaces and portable gas detectors are also required.

- **Automatic Safety Shutdown Systems**. The IGC requires that cargo loading areas and docks be equipped with LNG vapor and fire detection systems that automatically shut down the transfer systems in the event of a leak or fire. Personnel on the loading dock or the LNG carrier can also manually operate these shutdowns.

The technical requirements for vessels to carry LNG in U.S. waters are set forth in 46 CFR Subchapter D and 46 CFR 154. These regulations set forth a comprehensive framework for the certification, inspection and operation of tank vessels carrying LNG in bulk.

In addition to carrying a valid IMO Certificate of Fitness, and complying with the specific U.S. requirements for LNG carriers, foreign-registered LNG carriers operating in U.S. waters must also comply with the following U.S. regulations:

- Pollution prevention regulations (33 CFR Parts 151, 155-157 and 159)
- Navigation safety regulations (33 CFR Part 164)
- Repair regulations (46 CFR Part 35.01-1)

Foreign registered tank vessels must further comply with:

- Cargo venting and handling system requirements (46 CFR Part 35.30 and 35.35)
- Inert gas systems (46 CFR Part 32.53)

- Fire fighting foam systems (46 CFR Part 34-05-5(a)(2))
- Vapor control systems (46 CFR Part 39)

The process-related scenarios identified in the HAZID have not been further analyzed in this study. These scenarios were determined to have smaller potential release sizes (potential breach size, inventory available for release, and duration of release) and a lower potential to escalate (due to the safety and emergency shutdown systems) as compared to other accidental and intentional scenarios for which a detailed examination of the consequences has been performed. The lower likelihood for catastrophic accidental events is based on the codes, regulations, requirements, and additional spill controls to which Port Ambrose has committed for the LNG carriers, the safety record of the LNG industry (both onshore and transportation), and the associated safety features onboard an LNGRV. Therefore, while process releases are credible scenarios, they do not represent the bounding consequence for the range of accidental scenarios identified in the HAZID and have not been included in the IRA as a worst case consequence.

5.1.3 Weather-Related Release

The LNGRVs will monitor current and forecasted weather conditions through regular monitoring of the vessel's equipment (such as radar, barometer, anemometer, and visual observation from the bridge) as well as monitoring National Weather Service internet and VHF voice broadcasts of current and forecasted marine conditions, Dial-A-Buoy service from Station 44065-Entrance to NY Harbor, real-time weather radar satellite imagery via internet, and mass media weather broadcasts available by satellite on the vessel's TV system.

The Port Manager and LNGRV Master at the first sign of significant weather will determine the Master's needs and plans for storm evasion, such that any order to evacuate will be done in a manner timely enough to allow safe weather evasion. Evacuation due to forecasted weather in excess of the limits below will be ordered by the Port Manager in consultation with the LNGRV Master, and in accordance with the COTP New York Hurricane and Severe Weather Plan. Proper notifications and consultations with USCG will be made.

In addition the submerged turret loading (STL) system components are designed for:

- LNGRV to stay connected in the 10-year storm condition
- Idle system will survive the 100-year storm condition

The maximum sea state for connection of a LNGRV to a STL Buoy is:

- Significant wave height (Hs) 9.8 feet (3 m)
- Wind speed (Uw; 1 hour mean) 30 knots (15 m/second)
- Current speed (Uc) 2.9 knots (1.5 m/second)

The HAZID included severe weather at any point along the LNGRV transit and at the DWP. Due to the relatively predictable weather around the port, combined with the robust ship and equipment design, procedures to predict adverse weather conditions, and the ability to disconnect from the buoy should severe weather develop suddenly during transfer operations,[27] significant damage to an LNGRV or the DWP due to severe weather is considered unlikely.

[27] Port Ambrose Application, Vol. III, Sec. 9 (Draft Operations Manual)(Confidential).

5.1.4 Seismic Activity[28]

A system of near vertical normal faults, identified as the New York Bight Fault Zone, is located offshore approximately 9 miles (14.5 km) to the southeast of the city of Long Beach, New York. However, no surface expressions of faults were observed in the data collected during the shallow geophysical survey along the proposed pipeline corridor.

The seismicity of the New York Bight area of the United States has been relatively stable over the past several hundred years, with the earthquake activity being located at a mean depth of approximately 6 miles (10 km). For this reason, and since no active faults were identified during the geophysical surveys, risks to the proposed Project from fault activity are expected to be insignificant.

5.1.5 Aircraft Collision Release

The HAZID considered a large commercial jet, a smaller private jet, or a helicopter colliding with the LNGRV at any point in transit or at the DWP. Since the likelihood of such an accident with an aircraft not associated with the Port Ambrose project is remote, these types of aircraft scenarios have been screened out for further consideration.

5.2 Intentional Release Scenarios

As part of the HAZID, a thorough review of potential intentional attack scenarios against the LNGRV and DWP were developed. These included scenarios required by the USCG to be considered for development of a security vulnerability assessment and facility security plan under the Maritime Transportation Security Act (MTSA) such as standoff attack, ramming, hijacking, and other methods. Describing the weapons, tactics, and potential consequences in detail is not suitable for a public document; therefore, this combination of information is excluded from this report.

The probability of intentional attacks cannot be accurately determined based on historical data. Therefore potential events were not screened out based on any sort of frequency of occurrence. The selection of intentional scenarios for analysis was based solely on events that were deemed to be credible and that bound the potential consequences of a LNG release. Working with Sandia and the USCG, release scenarios have been defined for this risk assessment without associating the weapons or tactics. The intentional acts were evaluated in cooperation with Sandia who had input from local intelligence sources and the most significant of the credible threats identified were analyzed.

5.2.1 Intentional Scenario Breach Sizes

In preparing SAND2008-3153, Sandia met with intelligence agencies and other federal agencies to discuss potential threats against maritime shipping based on the possible capabilities and past actions of politically active groups. From these external and internal discussions with Sandia explosives and threat experts, a set of site-specific threat scenarios was developed to consider against the proposed Port Ambrose operations. As discussed previously, the threat scenarios developed are documented in a separate classified report.

[28] Port Ambrose Application, Vol. II, Section 7 (Public).

Using this set of credible threat scenarios, Sandia performed a series of scoping calculations to estimate the possible breach sizes for a standard membrane-type LNG carrier for this range of threat scenarios. These calculations were conducted using shock physics-based computer models that can calculate the impact of an explosion or an attack with an explosive weapon on a structure, such as a LNG carrier. In SAND2008-3153, Sandia suggested that for the larger 215,000 – 265,000 m^3 LNG carriers where there might be less surveillance or control in an offshore environment, the breach sizes for a range of credible intentional events might vary from 5-12 m^2, with an expected nominal intentional breach size of 12 m^2. Additionally, given that the potential for multiple threats and possible escalating damage to additional tanks from fires or from cryogenic damage from the spilled LNG, Sandia suggested that as many as three LNG tanks may be compromised from a single intentional event.

While these results provide an understanding of the possible range of breach sizes from potential intentional threats, the guidance in SAND2008-3153 suggests that the threat, breach, spill, and hazard analyses should be conducted on a site-specific basis. Therefore, Sandia worked with AcuTech and the USCG to conduct a threat assessment and breach evaluation for specific, credible intentional threat scenarios for the Port Ambrose DWP project. Sandia considered site-specific factors such as ship size and design, LNG volumes, port location, vessel operations, and traffic control and vessel protection to estimate the credible threats and the associated range of possible breach sizes to consider for fire and vapor dispersion hazard distance calculations.

Based on the assessment of these factors for the Port Ambrose DWP location, a range of credible breach sizes was developed for what was considered to be credible threats for this DWP location. While the methodology and breach size results for specific threats are classified, the maximum breach size results estimated for the LNGRV for this project are summarized below.

While the LNGRVs are moored at the Port Ambrose DWP, there is less traffic control, surveillance, and escorts, but the vessels are more difficult to access due to their distance offshore. Taking this into consideration, Sandia recommended the intentional breach sizes for membrane LNGRVs detailed in Table 5-1 be used in calculating LNG spill rates, spill volumes, and associated spill hazards for this project: Since there could be two LNGRVs at the Port Ambrose DWP to provide an uninterrupted flow of natural gas to the pipeline, the impacts of a breach of containment of one LNGRV on a LNGRV at the other buoy location was considered. Also considered was the possibility of a simultaneous attack against two LNGRVs while at the DWP.

Insulation proposed for the LNGRVs could potentially degrade in a fire. While the degradation will be most pronounced at the top of the cargo tanks where there is less shielding of the insulation, the potential of fire damage to additional cargo tanks and cascading spills should be considered. This scenario is represented by Scenarios 2 and 5 and addresses the insulation degradation cascading damage issues.

Table 5-1: Intentional Scenario Summary

Scenario	Description	Event Type
Membrane-Type Carrier - 145,000m^3		
1	One - 16m^2 hole (single cargo tank release)	Intentional
2	Two - 12m^2 holes (two cargo tank release)	Intentional (Cascading Damage)
3	One – 2m^2 hole (single cargo tank release)	Hijacking
4	Two - 5m^2 holes (single cargo tank release)	Hijacking
5	Two - 5m^2 holes (two cargo tank release)	Hijacking (Cascading Damage)

5.3 Vessel Collision Scenario Breach Sizes

Vessel collision had been discussed in the context of both accidental and intentional events. The more extreme result would be associated with an intentional event where no attempt is made to reduce the speed of the striking vessel. However, similar results would be produced by a vessel that is moving at standard speeds but inadvertently strikes an LNGRV calling on the DWP. The analysis performed here addresses both of these potential events.

The severity of a breach from a LNGRV following a collision with another vessel depends on the location of impact, vessel design, relative vessel speeds, collision alignment, and mitigation or prevention systems in place to limit the potential damage. For the Port Ambrose DWP, the applicant is proposing membrane-type LNG carriers. Therefore, this design option has been examined in this section of the IRA to determine the breach size that will be applied in the consequence analysis for the vessel collision scenario.

5.3.1 Calculation of Absorbed Energy

Breaches to membrane-type LNGCs are found to be a function of the kinetic energy of the striking vessel and the energy absorbed by the LNGC. These calculations are applicable to both membrane- and Moss-type LNGCs, as well as the LNGRVs for the Port Ambrose Project, and have been proven in earlier DWP IRAs.

Displacement of the vessels is important and is given by the relationship

$$\text{Displacement} = 1.026 \text{ x } C_b \times \text{Length} \times \text{Breadth} \times \text{Draft}$$

where C_b is the Block coefficient which depends on vessel type as listed in Table 5-2 and the size dimensions are in units of meters.

Table 5-2: Block Coefficient for Various Vessel Types

Vessel Type	C_b
Tanker	0.85
Passenger	0.68
Cargo	0.61
Other	0.75

In calculating the energies, the first key parameters are the mass of the striking vessel (M) and the mass of the struck vessel (m). The total energy associated with the striking vessel is also dependent on the entrained water moving with the vessel. This is related to the mass of the vessel using the parameter D and values of 0.05 to 0.1 are typically used. The mass of the water that is moving along with the striking ship, either by being pushed in front of the vessel or by being dragged along due to friction over the length of the hull. The upper end of the range, specifically a value of 0.1, has been applied in the current calculations.

The absorbed energy is also dependent on the resistive mass that acts on the struck vessel. This can be related as a ratio (d) of added mass relative to the vessel. Minorsky[29] recommended 0.4 times the mass of the struck vessel, and that ratio has been widely used. The initial kinetic energy (E_1) of the striking vessel is correlated to the vessel's initial velocity (V) prior to impact and associated mass through the relation

$$E_1 = ½ (M + DM)V^2$$

For this study it is assumed the struck vessel is initially at rest and assuming a perfectly plastic collision both vessels reach the same final velocity (U) and the initial momentum, given by

$$H_1 = (M + DM)V$$

Equals the final momentum

$$H_2 = (M + DM + m + dm)U$$

conservation of momentum gives H1=H2 which results in

$$U = [(M + DM)/(M + DM + m + dm)]V$$

and the associated final kinetic energy is

$$\begin{aligned} E_2 &= ½ (M + DM + m + dm)U^2 \\ &= ½ (M+DM+m+dm)*[(M+DM)/(M+DM+m+dm)]^2*V^2 \end{aligned}$$

[29] V.V. Minorsky, "An Analysis of Ship Collisions with Reference to Protection of Nuclear Power Plants", Journal of Ship Research, Vol. 3, No. 1 (1959), pp. 1-4.

which simplifies to

$$E_2 = [(M+DM)/(M+DM+m+dm)]*E_1$$

The absorbed energy is the difference in the initial and final kinetic energies and is

$$E_{absorbed} = E_1 - E_2 = \{1-[(M+DM)/(M+DM+m+dm)]\}*E_1$$

5.3.2 Marine Traffic Data

As detailed in Section 5.3.1, the breach size resulting from an impact of a vessel with a LNGRV is a function of the striking ship. This information was made available through AIS data provided by the USCG. Using this information it was possible to establish a range of impact kinetic energies for potential striking ships. This information is summarized in Table 5-3 and will be used in determining the size of breaches due to accidental events.

Table 5-3: Vessel Type and Impact Energy

Vessel Type	Displacement (tonnes)	Max Cruising Speed (knots)	Kinetic Energy (N-m)
Passenger	84 – 127,738	28.1	$6.49 \times 10^5 - 1.11 \times 10^{10}$
Cargo	2,379 – 169,153	24.8	$2.97 \times 10^7 - 1.24 \times 10^{10}$
Tanker	1,744 – 183,141	17.7	$1.51 \times 10^5 - 4.93 \times 10^9$

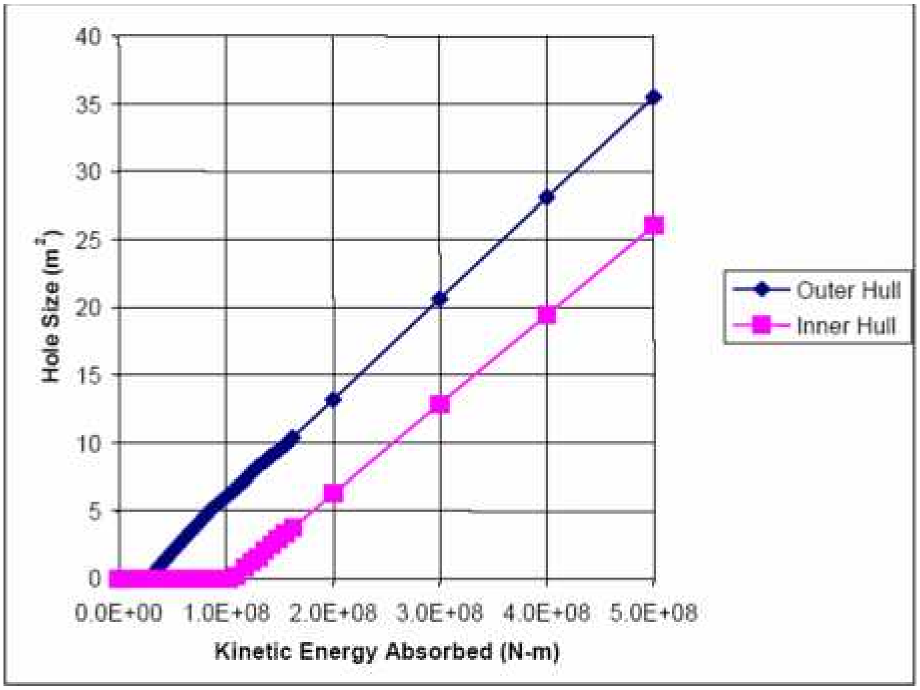
5.3.3 Calculations for Determining Breach Size for a Membrane-Style Cargo Tank

This study uses the approach applied in earlier LNG IRA studies. To fill the void of published work relating damage to LNGCs and LNGRVs (inner hull breach size) to striking vessel type, speed, and energy, Sandia National Labs conducted computational studies. This work included finite element modeling of collisions for a series of double hulled oil tankers, similar in overall size, mass, and design to a membrane-type LNGRV.[30] A result of this analysis is a set of curves useful in estimating the breach size on the outer and inner hull of a membrane-type LNG carrier as a function of the energy of the collision. This relationship, replicated from the Sandia Report, is shown in Figure 5-1.

While membrane-type LNG carriers and crude oil tankers differ, the nature of the double hull vessels are closer in design and response than traditional single hull tankers, where most of the empirical collision data has been obtained. Therefore, the recommendations in SAND2004-6258 were used to assess the expected inner hull breach size for a membrane-type LNGRV following a collision with a passing vessel.

[30] SAND2004-6258 Appendix B

Figure 5-1: Double Hull Tanker Hole Size vs. Kinetic Energy (SAND2004-6258)



The methodology for calculating the size of an inner hull breach in a membrane-type LNGRV (from a vessel-to-vessel collision) was developed with input from the USCG and Sandia, and includes the following steps:

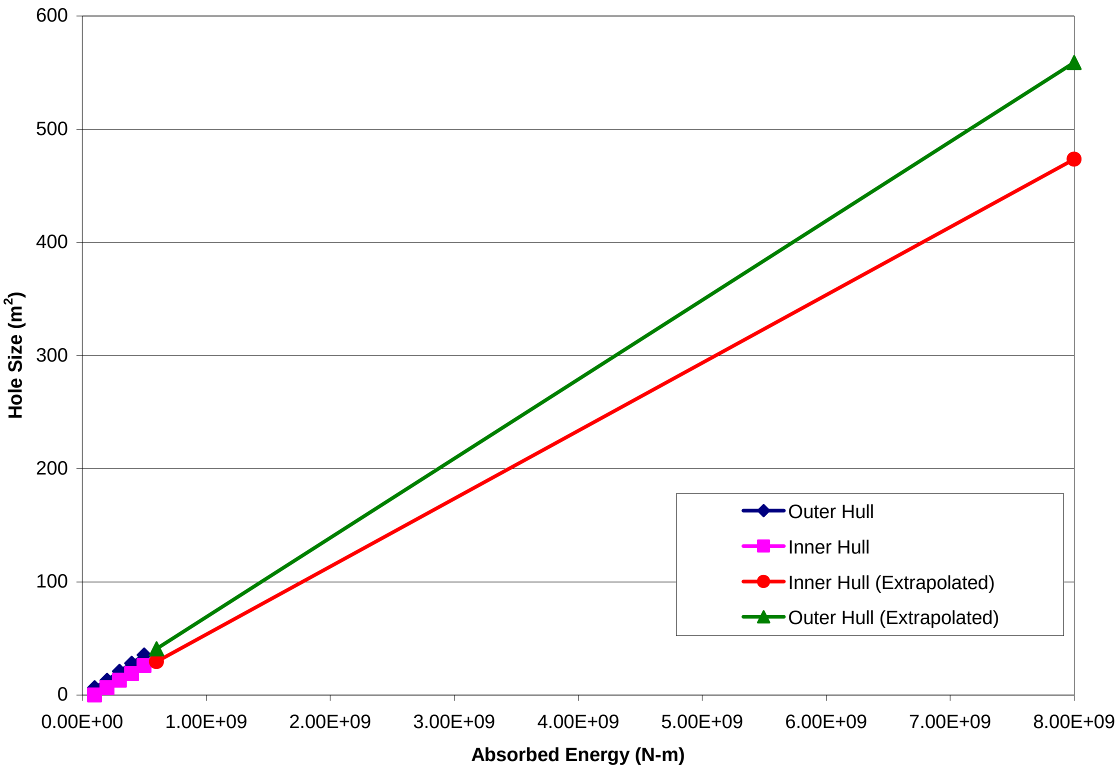
- Calculate the kinetic energy of the vessels with the potential to collide with the LNG carriers for this project. The range of potential vessels is based on the AIS data from the USCG R&D Center, and the kinetic energy is calculated for each striking vessel based on the specific displacement and speed of each vessel.

- Calculate the absorbed energy of the LNGRV based on the kinetic energy of the striking vessel.

- Calculate the final breach size that will be applied in the vessel collision consequence modeling.

Based on discussions with Sandia and the USCG, it was determined that the empirical equations used for ship collisions can be represented as a linear relationship between breach size and absorbed energy. The curves presented in Figure 5-2 were extrapolated by AcuTech (from the data in SAND2004-6258) to determine the breach sizes for collisions with a membrane-type LNGRV.

Figure 5-2: Extrapolated Breach Size vs. Absorbed Energy Curve (Membrane-type LNGC and LNGRV)



Using this information, the methodology for calculating the size of an inner hull breach in a membrane-type LNGRV (from a vessel-to-vessel collision) includes the following steps:

- <u>Calculate the kinetic energy</u> of the vessels with the potential to collide with the LNG carriers for this project. The range of potential vessels is based on the AIS data from the USCG R&D Center, and the kinetic energy is calculated for each striking vessel based on the specific displacement and speed of each vessel.
- <u>Calculate the absorbed energy</u> of the LNGRV based on the kinetic energy of the striking vessel.
- <u>Determine 90th percentile absorbed energy</u>: While the maximum absorbed energy can be calculated, it is only representative of the worst-case or a single and specific vessel transiting near the DWP location. The 90th percentile absorbed energy is a more representative upper bound, eliminating outliers in the upper end of the AIS dataset.
- <u>Extrapolated hole size</u>: Use Figure 5-2 to determine for the 90th percentile absorbed energy the corresponding hole size.

- Calculate the final breach size: The work of Ammerman[31] has been used to support reducing the predicted extrapolated breach size resulting from an accidental collision with LNGRVs[32]. Ammerman's work was originally commissioned to provide a comparative analysis of oil outflow from breached cargo tanks among double hull crude oil carriers. The hypothesis that Ammerman's work supports is that the striking ship remains lodged in the structure of the damaged vessel thus reducing the outflow of cargo. This reduction in extrapolated breach size (a value of 90%) was informally derived from a survey of worldwide tanker collision events. This approach is consistent with Ammerman's double-hull tanker study.

Table 5-4 details the results for the data associated with the proposed Port Ambrose DWP site. The results show that the largest breach size for a collision with a membrane-type LNGRV would be due to a collision with a cargo vessel and would result in a breach size of 23.1 m^2.

Table 5-4: Estimated Vessel Collision Parameters (Membrane LNGRV)

Parameter	Vessel Type			
	Passenger	Cargo	Tanker	Other
Number of Vessels (per year)	107	2,117	1,121	94
Maximum Absorbed Energy (N-m)	5.63×10^9	6.05×10^9	2.16×10^9	2.45×10^9
90^{th} Percentile Absorbed Energy (N-m)	3.96×10^9	3.45×10^9	1.64×10^9	4.31×10^8
Extrapolated Hole (m^2)	231	200	92	18
Breach Size (m^2)	23.1	20.0	9.2	1.8

In these calculations, only the three vessel types (passenger, cargo, and tanker), and only those vessels within this subset with the appropriate combination of displacement and speed have been included in the estimation of the resultant collision breach size of a membrane-type LNGRV. Therefore, any vessels from the AIS dataset passing the DWP location with an absorbed energy of less than 1.0×10^8 N-m are not included, as these would not result in a calculated inner hull breach[33]. This minimum absorbed energy for inner hull damage is illustrated in Figure 5-1.

While there is a potential for post panamax vessels entering the NYNJ in the future, given the low number of LNGRV receipts to Port Ambrose (up to 45 per year) and low number of future post panamax vessels entering NYNJ port, the probability of their collision with an LNGRV is extremely remote. Additionally, as the 90th percentile absorbed energy which is a more representative upper bound, is used to determine the release size from a collision with the LNGRV (as compared to the maximum energy), no significant difference in maximum breach size is expected. Therefore, post panamax vessels are not considered in the collision analysis.

[31] Ammerman, D.,"Marine Safety Systems, Control Ballast Tanker Interactive CD," SAND2002-3188P, (Albuquerque, NM: Sandia National Laboratories, 2002).
[32] SAND2004-6258.
[33] It is possible that there may be two LNGRVs at the Port Ambrose DWP simultaneously to ensure constant natural gas supply. These LNG vessels do not have sufficient kinetic energy at their approach speed within the safety zone to result in an inner hull breach if a collision between two LNG project vessels were to occur. Therefore, the LNGRVs have been screened out from further consideration in these calculations.

6.0 Vessel Collision Frequency Analysis

This section focuses on the frequency of collisions between ships and between ships and a fixed object. A ship striking a fixed object is formally referred to as an allision. Although LNG regasification vessels (LNGRVs) moored at the deepwater port (DWP) buoys can weathervane with the wind and current, they are not underway while unloading at a DWP. Nevertheless, for the purposes of this analysis, a ship striking a moored LNGRV will be referred to as a collision.

A powered collision for the Port Ambrose project may involve:

- Collisions between an LNGRV and ships transiting near the proposed DWP (typical associated with New York Harbor) and under way.

A drifting collision may involve any of the following:

- Collisions between an LNGRV and ships transiting near the proposed DWP (typical associated with New York Harbor) that loses steerage.

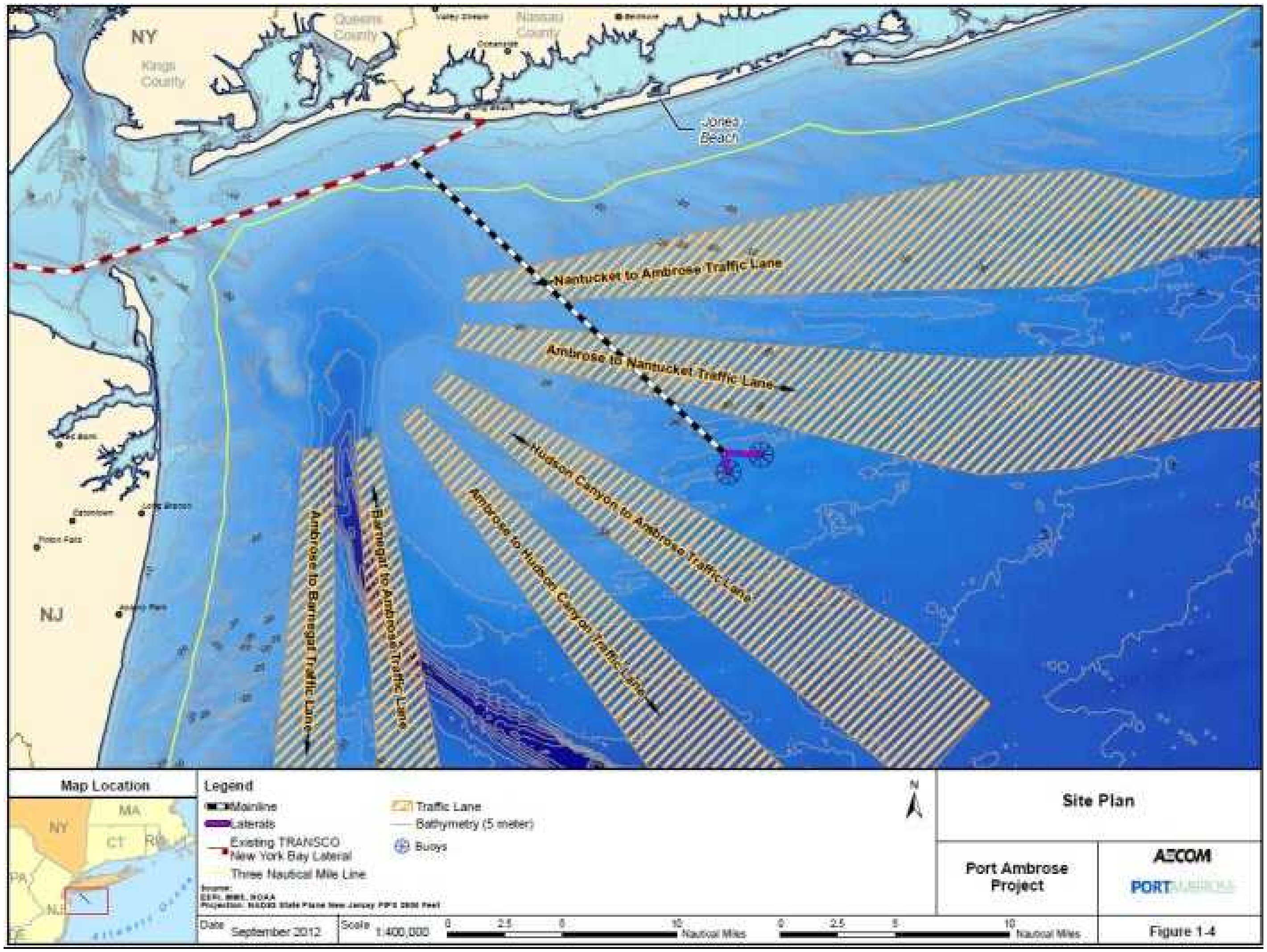
Passing vessel collisions for the Port Ambrose project can be divided into two categories. The first category is for vessels transiting in defined routes (or shipping lanes), represented by vessels that use the Ambrose to Nantucket line and the Hudson Canyon to Ambrose lane. The second category is for randomly distributed vessels near the DWP.

The vessel fairways are presented in Figure 6-1, with the Port Ambrose DWP located approximately 3.3 nautical miles from the center (2.0 nautical miles to the edge) of the Ambrose to Nantucket lane, and 3.7 nautical miles from the center (2.9 nautical miles from the edge) of the Hudson Canyon to Ambrose lane.

Vessel traffic data to be used in the analysis was provided by the U.S. Coast Guard (USCG) R & D Center. The data is the Automatic Identification System (AIS) which provides the vessel details in terms of size and the location and speed. This data is used to establish the traffic distribution for use in the analysis of powered collision by vessels in the shipping lanes.

The AIS dataset for this project indicates that there are vessels that pass the proposed DWP location, but do not use a defined route (a formal or informal shipping or transit lane). Additionally, the data indicates that some of these vessels do have sufficient displacement and speed to result in an inner hull breach of the LNGRV in a collision. Therefore, the frequency of these vessels colliding with an LNGRV at the DWP has been evaluated as part of this analysis.

Figure 6-1: Port Ambrose Buoy Locations and Safety Fairway



6.1 Collision Analysis

The AIS data that was collected for the Port Ambrose project area included not only all vessel traffic, but also data to identify vessels with sufficient displacement, speed, and kinetic energy to breach the inner hull of a LNGRV. Section 5 presents the LNGRV inner hull damage calculations for vessel collisions. As detailed in this section, only vessels with the combination of displacement and speed that can result in an absorbed collision energy with the LNGRV of 1.0×10^8 N-m or greater have the potential to breach the inner hull of the LNGRV. This level of absorbed energy is the minimum required to breach the hull of a membrane-style LNGRV. The remaining vessels[34] are assumed to be incapable of causing an inner hull breach of the LNGRV, and a collision with these vessels is assumed not to result in a release of LNG.

Using the subset of AIS data (vessels with absorbed collision energy of 1.0 x 10 N-m or greater), there are 3,702 annual vessel movements in the defined lanes to the north and south of the proposed Port Ambrose DWP. Of these annual vessel movements, 1,794 vessels were traveling in the Ambrose to Nantucket lane and 1,908 vessels were traveling in the Hudson Canyon to Ambrose lane. All of these vessel movements have the potential to breach the inner hull of the LNGRV at cruising speed.

Given the low number of LNGRV receipts to Port Ambrose (up to 45 per year) and low number of future post panamax vessels, additional post panamax vessels is not expected to have a significant impact to the vessel collision frequency analysis.

6.1.1 Powered Collisions

The frequency of powered collisions is given as follows. This model was developed by DNV and has been used for ship collision analyses for DWP application IRAs over the past four years.[35] .

$$F_{power} = N \times P_{coll} \times P_2 \times P_3$$

Where:
F_{power} = Frequency of powered collision, per year
N = Number of transits in safety fairway or other route, per year
P_{coll} = Probability of collision
P_2 = Probability of steering system failure when on collision course = 2.0×10^{-4}
P_3 = Probability of failure to recover from collision course given a warning from moored LNGRV = 0.67

The selection of the probability distribution function (P_{coll}) depends on the route followed by the vessels transiting past the LNGRV. Since the powered collision is only considering vessels in the Ambrose to Nantucket lane and the Hudson Canyon to Ambrose lane, the vessels in the safety fairway can be represented as a skewed normal distribution between each fairway and the DWP.

[34] In the future, it is possible that there may be up to two LNGRVs at the Port Ambrose DWP simultaneously to ensure constant natural gas supply. These LNG vessels do not have sufficient absorbed energy at their approach speed within the safety zone to result in an inner hull breach if a collision between two LNG project vessels were to occur. Therefore, the LNGRVs have been screened out from further consideration in these calculations.
[35] Det Norske Veritas (DNV), *Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU)*. Final Report, March 14, 2003, Project No. 230-11749.

There are many skewed continuous distribution functions that can be used to model the vessel routes. After reviewing these, the Rayleigh distribution function was selected for its simplicity. It is defined with only one parameter, namely the mode, *b*. For application to vessels in the safety fairway, a value of *b* of 0.5 nm was selected, and is consistent with an assumption that vessels could deviate up to one-half mile to pass other vessels, or that the vessels may drift within the safety fairway since it is not a defined traffic separation scheme (TSS).

The Rayleigh probability density function is P(r):

$$P(r) = \frac{r}{b^2}\exp\left[-0.5\left(\frac{r}{b}\right)^2\right]$$

The cumulative distribution function is D(r):

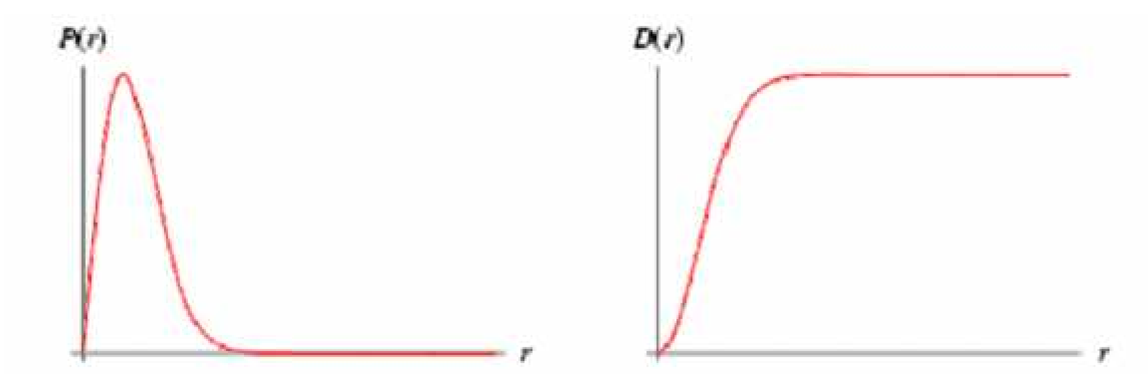
$$D(r) = 1 - \exp\left[-0.5\left(\frac{r}{b}\right)^2\right]$$

Where:

- D(r) = Cumulative distribution function
- r = Distance from the DWP buoys to marine traffic track or lane (when measuring distances to the safety fairway, the distance from the DWP to the edge of the AIS identified vessels in the fairway was used)
- b = Mode value of distribution = 0.5 nm

The form of the Rayleigh distribution function is shown in Figure 6-2.

Figure 6-2: Rayleigh Probability Density and Cumulative Distribution Functions



To determine the probability that a LNGRV will be within the distance defined by the mode of the distribution (i.e., 0.5 nm), the value of D(r) must be calculated for two distances: the distance from the moored LNGRV to the safety fairway or track plus half the length of the LNGRV, and the distance from the moored LNGRV to the safety fairway or track minus half the length of the LNGRV.

Therefore, the two distances are:

$$r_1 = r + 0.5(\text{length of LNGRV})$$

$$r_2 = r - 0.5(\text{length of LNGRV})$$

The length of the LNGRV is 280 m. Once D (r_1) and D (r_2) are determined, the probability of collision is the difference between these two values:

$$P_{coll} = D(r_1) - D(r_2)$$

Table 6-1 shows a summary of the P_{coll} calculations for the DWP locations with respect to the Ambrose to Nantucket lane (North Fairway) and Hudson Canyon to Ambrose lane (South Fairway). As shown in Table 6-2:

- Probability of powered collision with Buoy #1 = 8.00 x 10^{-9}
- Probability of powered collision with Buoy #2 = 2.31 x 10^{-5}
- Probability of powered collision with DWP = 2.13 x 10^{-5}

Table 6-1: Summary of Calculated Pcoll Values[36]

Description of DWP Buoy & Traffic Location	Distance from DWP Buoy to Safety Fairway/Route, r (nm)	r_1 (nm)	r_2 (nm)	D(r_1)	D(r_2)	P_{COLL}
Buoy #1 (to North Fairway)	3.5	3.575594	3.424406	1	1	5.74 x 10^{-11}
Buoy #1 (to South Fairway)	3.0	3.075594	2.924406	1	1	3.12 x 10^{-8}
Buoy #2 (to North Fairway)	2.2	2.275594	2.124406	0.99996	0.99988	8.84 x 10^{-5}
Buoy #2 (to South Fairway)	4.5	4.575594	4.424406	1	1	0

Table 6-2: Summary of Frequencies of Powered Collisions

Description of DWP Buoy & Traffic Location	N	P_{COLL}	P_2	P_3	F_{POWER}
Buoy #1 (to North Fairway)	1,794	5.74 x 10^{-11}	2.00 × 10^{-4}	0.67	1.38 x 10^{-11}
Buoy #1 (to South Fairway)	1,908	3.12 x 10^{-8}	2.00 × 10^{-4}	0.67	7.98 x 10^{-9}
Buoy #2 (to North Fairway)	1,794	8.84 x 10^{-5}	2.00 × 10^{-4}	0.67	2.13 x 10^{-5}
Buoy #2 (to South Fairway)	1,908	0	2.00 × 10^{-4}	0.67	0

[36] Based on the calculations performed for the Table 6-1 values, it is clear that for any value of r that is greater than 4.0 nm, the values of D(r_1) and D(r_2) become so small (< 1 X 10^{-12}) that the value of P_{coll} approaches zero. Therefore, for any combination of vessels either in the vessel safety fairway or at a distance of more than 4.0 nm, the probability of collision is calculated as zero.

6.1.2 Drifting Collisions

Drifting collisions are possible at the proposed DWP location if a vessel in the safety fairway loses propulsion and the wind and current cause the damaged vessel to collide at low speed with a moored LNGRV. As with powered collisions, the only vessels of concern are those with the requisite mass at the assumed drifting speed that have enough kinetic energy to possibly breach the inner hull of a LNGRV. The drifting speed of a vessel is dependent on the vessel type/size and the wind speed.[37] The weather at the DWP location was evaluated by reviewing data from the National Oceanic and Atmospheric Administration (NOAA), National Buoy Data Center. Specifically for this Port, data from Station 44025 – Long Island – 30 NM South of Islip, NY was collected and reviewed. The prevailing wind speed at the DWP is 10 m/s (19.4 kts). This wind speed translates into a Beaufort Wind Strength of 6[38], and for the larger passenger, cargo and tankers operating near the DWP, a drifting speed of 1.7 kts is applied for this analysis. Using the displacement data from the AIS and a speed of 1.7 kts, there are no vessels surrounding the Port Ambrose area of operation that have the potential to breach the inner hull of a LNGRV in a drifting collision. Specifically, there is no vessel of sufficient displacement drifting at a speed of 1.7 kts that would result in an absorbed energy of 1.0×10^8 N-m or greater. Based on these results, the frequency of a drifting collision between a vessel in the safety fairway and an LNGRV at the DWP is not considered.

6.1.3 Randomly Distributed Vessels

The underlying technical basis for the collision frequency for randomly distributed vessels was published by DNV (2003).[39]

As discussed, the AIS dataset for this project shows vessel traffic near the proposed DWP with no defined routes. Additionally, there is a subset of these randomly distributed vessels that have sufficient displacement and cruising speed to result in an inner hull breach of the LNGRV in a collision.

In this analysis, the vessel traffic with a collision absorbed energy potential of 1.0×10^8 N-m or greater is defined in terms of a density (i.e., the number of vessels per square nautical mile). The collision frequency model for random vessel motion is outlined below.

$$F_{random} = N \times P_1 \times P_2 \times P_3$$

Where:
$N = \rho \times \pi \times R^2$ = the number of vessels within a circle with radius R
ρ = density of vessels (vessels/m^2)
$R = 365 \times 24 \times 3600 \times V$ = the distance traveled in one year
V = vessel speed (m/s)
$P_1 = D/(\pi \times R)$ = the mean geometric collision probability
D = collision diameter of the LNGRV (m)
P_2 = probability of loss of control onboard the ship
P_3 = probability of failure of warning or diverting a ship on collision course

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[37]Centre for Marine and Petroleum Technology (CMPT), "A Guide to Quantitative Risk Assessment for Offshore Installations," 1999.
[38] http://www.spc.noaa.gov/faq/tornado/beaufort.html
[39]DNV Project No. 230-11749, 2003.

For this calculation, the values for P_2 and P_3 are the same as for the powered vessel collision calculation, Section 6.1. Specifically:

- $P_2 = 2.0 \times 10^{-4}$
- $P_3 = 0.67$

From the AIS dataset, it can be assumed that vessels with sufficient displacement to breach the inner hull of the LNGRV could be passenger vessels, cargo vessels, or tankers. The average cruising speed for these vessel types, at this distance from shore, is approximately 12.2 kts (6.3 m/s).

Evaluating the vessel traffic around the DWP for vessels with the potential to breach the inner hull of the LNGRV in a collision:

- Buoy #1: There are approximately 223 vessels (between the defined shipping lanes) in a given year (density = 1.21×10^{-5} vessels/ meter^2)
- Buoy #2: There are approximately 144 vessels (between the defined shipping lanes) in a given year (density = 5.57×10^{-6} vessels/ meter^2)

Since these vessels can approach the DWP from any direction, the collision diameter (D) of the LNGRV is equal to the average apparent width of the LNGRV.

$$D = (\text{Length} + \text{Beam}) \times 2 / \pi$$

Given an LNGRV length of 280 meters and a beam of 43 meters, D is calculated to be 205.6 meters.

Using the collision frequency calculation above, and the listed assumptions, the collision frequency for vessels randomly passing the DWP is calculated to be 1.67×10^{-8} collisions per year (one collision that could result in an inner hull breach of the LNGRV every 59,862,372 years). It should be noted that this frequency does not take into account any safety and security zones and or ATBA that may be established as part of the DWP. In addition to collision detection and avoidance systems that may be placed on both the LNGRV and the potential colliding vessel, the actual likelihood of a vessel collision with an LNGRV at the DWP by a passing vessel would be expected to be much lower than calculated.

6.2 Final DWP Collision Frequencies

The final frequencies for collisions between various deep draft vessels transiting the New York Harbor area and LNGRVs moored at the Port Ambrose DWP locations are shown below.

The total frequency of a collision with an LNGRV at the DWP was calculated for two vessel types: 1) vessels in the established Ambrose to Nantucket lane and Hudson Canyon to Ambrose lane; and 2) vessels randomly passing the DWP location. This calculation utilized vessel traffic from the AIS dataset for this project and only included those vessels with the potential to breach the inner hull of the LNGRV in a collision. Table 6-3 shows the summary of the annual collision frequency for the DWP location.

Table 6-3: Frequency of Vessel Collisions for Proposed DWP

TRAFFIC LOCATION	ANNUAL FREQUENCY OF COLLISION (COLLISION PER YEAR)	COLLISION ESTIMATED PERIOD (YEARS PER COLLISION)
Ambrose to Nantucket Lane	2.13×10^{-5}	1 collision every 47,000 years
Hudson Canyon to Ambrose Lane	7.98×10^{-9}	1 collision every 125,000 years
Randomly Distributed	1.67×10^{-8}	1 collision every 60,000 years
TOTAL	$\mathbf{2.13 \times 10^{-5}}$	**1 collision every 47,000 years**

7.0 Consequence Analysis

This section includes a discussion of the modeling approach to the consequence analysis as well as a discussion of the modeling parameters and bounding conditions applied to the models.

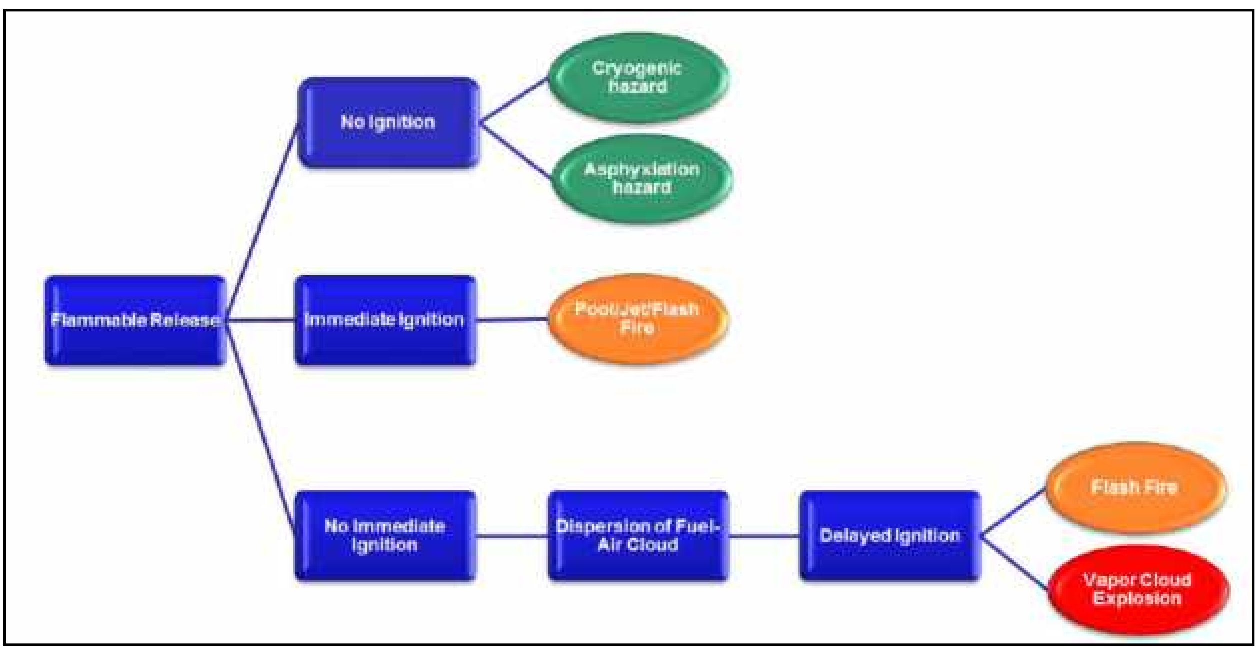
The LNG spill scenarios were modeled using the tools (computational fluid dynamics and solid flame models) required by the USCG Guard for this type of analysis. In particular, the FLACS computational fluid dynamics (CFD) tool was used to determine LNG pool spreading and vaporization and LNG vapor dispersion. A solid-flame model based on calculations performed by FERC staff was used for the thermal radiation calculations, and the pool fire radiant heat flux hazard distance analysis was performed according to the parameters specified by Sandia following their large scale LNG pool fire experiments.

Conservative assumptions were made throughout the analysis, to increase the margin of safety in the simulations.

7.1 Scope

The scope of the consequence analysis for this Independent Risk Analysis (IRA) is to estimate the thermal radiation and flammable vapor dispersion hazards from the accidental and intentional release scenarios developed in Section 5. The impacts that are evaluated for these hazards are consistent with injuries to humans and damage to property. A large scale release is defined as any release of LNG in which the spilled LNG volume and flow rate are greater than those obtained from process systems failures (e.g., pipe or valve failures). Figure 7-1 shows the event tree following a large scale release of LNG over water.

Figure 7-1: Event Tree for a Large-scale LNG Release over Water



Of the four potential consequences of an LNG release shown in the event tree (i.e., pool fire, flash fire, vapor cloud explosion and no event), the thermal radiation hazard zones from pool fires and the flammable vapor dispersion that defines the extent of a flash fire are specifically addressed in the IRA. These consequence types have the potential to impact the public surrounding the deepwater port (DWP). The reasons the other consequence types are not specifically addressed in a DWP IRA are:

- Vapor Cloud Explosion: The release of a flammable material may lead to a vapor cloud explosion if ignited. A vapor cloud explosion results from the rapid combustion of a fuel/air cloud with the flame speed approaching sonic velocity, thereby producing a blast wave. Turbulence is required for the acceleration of flame front to speeds required to produce the blast overpressure associated with an explosion. In the absence of turbulence, a flash fire will occur without any appreciable overpressure. Flame turbulence is typically formed by the interaction between the flame front and obstacles. For this DWP location, vapor cloud explosions are not considered likely, given the absence of other structures that could provide confinement of the flammable vapor cloud.
- Cryogenic: Defined as a "no event" in Figure 7-1, cryogenic contact hazards are limited to areas that can be reached by the LNG pool. Based on available pool size estimates,[40] cryogenic contact hazards are not expected to extend far enough from the proposed project to affect the public.
- Asphyxiation: Defined as a "no event" on Figure 7-1, a risk of asphyxiation from LNG vaporization may be present if the gas concentration is sufficiently high to reduce the oxygen concentration below tolerable levels. A literature review by Sandia[41] indicates minimal frequency of permanent injury to the general population for oxygen levels above 14%. As the vapor cloud disperses away from the LNG pool, the gas concentration decreases and so does the risk of asphyxiation. Since the public will not be allowed within the Safety Zone around the LNGRV, asphyxiation hazards to the public are not considered to be an issue in this study.

7.2 FLACS Model

The LNG vapor dispersion calculations included in this report were performed using GexCon's CFD modeling software FLACS. FLACS is a widely used computational fluid dynamics (CFD) model, which has been extensively validated for the dispersion of LNG and other dense vapor clouds, additional details on the FLACS CFD model are provided below. The thermal radiation calculations were performed using a solid flame-based pool fire model, which utilizes correlations based on experimental data published in the Society of Fire Protection Engineers' (SFPE) Handbook of Fire Protection Engineering.[42]

FLACS, developed and maintained by GexCon AS in Norway, is a computational fluid dynamics (CFD) tool to model ventilation (i.e., natural or mechanical air flow), gas dispersion, gas/vapor cloud explosions and blast propagation in three-dimensional geometries, such as complex process areas.

A two-dimensional shallow water-based model was developed a few years ago to simulate the spreading and vaporization from liquid spills (e.g., from LNG releases). The 2D pool model is fully coupled with the 3D atmospheric dispersion model, resulting in a unified environment in which the

[40] SAND2004-6258.
[41] Ibid., pg. 117.
[42] SFPE Handbook of Fire Protection Engineering, 3rd Edition, edited by P. DiNenno, National Fire Protection Association, Quincy, MA (2002).

entire scenario (liquid spill and vapor dispersion) can be simulated efficiently and accurately. The pool model in FLACS is based on the well-established shallow water model,[43] which assumes that the pool thickness is much smaller than its horizontal dimensions; in that case, all properties of the pool (temperature, density, velocity, etc.) can be approximated as locally uniform over the thickness for the liquid layer. The FLACS pool model thus allows for the formation and spreading of the pool, accounting for the presence of obstacles and sloped terrain. The time-dependent evaporation rate is calculated locally (grid cell by grid cell) and is the sum of contributions from heat transfer from the substrate (ground or water), solar radiation and convective heat transfer.[44] The rate of vapor generation is also affected by physical variables such as local wind speeds and turbulence levels, as well as the local vapor pressure above the pool, all of which can be calculated at every time step due to the simultaneous solution of both the liquid pool spread and the vapor cloud dispersion.

Model validation has been a critical component of FLACS development since its inception.[45] As a result, a large database of FLACS validation examples currently exists which includes gas dispersion[46,47] and vapor cloud explosion experiments,[48] spanning from laboratory-scale to full-scale experiments performed by several different groups. Several of the validation studies, particularly the most recent ones, consist of blind validation exercises (i.e., the simulations were performed prior to or without knowledge of the experimental results) and demonstrate the ability of FLACS software to accurately predict gas dispersion and explosion scenarios without "tweaking".

7.3 LNG Release Scenarios

As detailed in Section 5, a subset of the release scenarios based on the HAZard IDentification (HAZID) process, led by AcuTech, were selected for inclusion in the risk assessment. The identified scenarios represent the worst credible scenarios, or the bounding scenarios. These scenarios lead to large scale releases of LNG from either a 145,000 m^3 membrane-style LNGRV:

- Scenario 1: Intentional attack leading to a 16 m^2 breach in a single tank
- Scenario 2: Intentional attack leading to a 12 m^2 breach in two (2) tanks
- Scenario 3: Hijacking attack leading to a 2 m^2 breach in a single tank
- Scenario 4: Hijacking attack leading to a 5 m^2 breach in a single tank
- Scenario 5: Hijacking attack leading to a 2 m^2 breach in two (2) tanks
- Scenario 6: Vessel collision/allision leading to a 23.1 m^2 breach in a single tank

[43] Fannelop, T. K., & Waldman, G. D. (1971). Dynamics of oil slicks. AIAA Journal, 10, 506-510

[44] Hansen, O. R., Melheim, J. A., & Storvik, I. E. (2007). CFD-modeling of LNG dispersion experiments. In AIChE spring national meeting, 7th topical conference on natural gas utilization, Houston, USA

[45] Hjertager, B.H., Bjørkhaug, M., Fuhre, K. (1988). Gas explosion experiments in 1:33 scale and 1:5 scale; offshore separator and compressor modules using stoichiometric homogeneous fuel–air clouds. J. Loss. Prev. Process Ind. 1, 197–205

[46] Venetsanos, A. G., Papanikolaou, E., Delichatsios, M., Garcia, J., Hansen, O. R., Heitsch, M., et al. (2009), "An intercomparison exercise on the capabilities of CFD models to predict the short and long term distribution and mixing of hydrogen in a garage," International Journal of Hydrogen Energy 34(14): 5912–5923

[47] Middha, P., Ichard, M. & Arntzen, B. (2010). Validation of CFD modelling of LH2 spread and evaporation against largescale spill experiments. International Journal of Hydrogen Energy, 36: 2620-2627

[48] Hjertager, B.H., Bjørkhaug, M., Fuhre, K. (1988). Explosion propagation of nonhomogeneous methane-air clouds inside an obstructed 50 m3 vented vessel. J. Haz. Mater. 19, 139–153

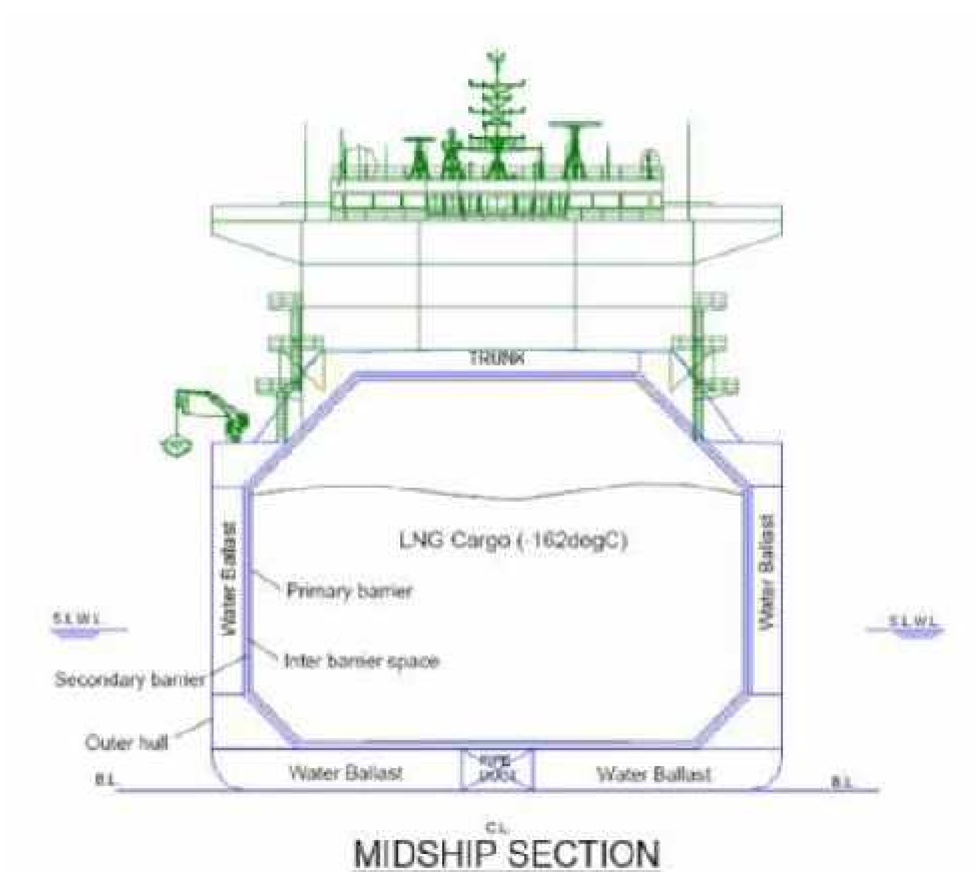
The outcome of the consequence assessment for each of these scenarios will be affected by the choice of the modeling tools as well as of the numerical values used for the various parameters, such as ambient conditions, that affect the modeling results. This section discusses some of the assumptions made in this study, as well as the parameter values used in the analysis, with the basis for their selection.

The scope of the consequence modeling does not include an estimate of the probability of occurrence of any one of the above four scenarios.

7.3.1 Breach Locations

The total volume of LNG spilled as well as the flow rate of LNG through a tank breach in a LNG regasification vessel (LNG RV) depends on the location of the hole. The LNG spill volume and flow rate are maximum for holes at the waterline – in fact, if the hole is below the waterline, the flow of LNG out of the tank is decreased by the backpressure caused by the water above the hole (water is heavier than LNG and therefore the hydrostatic pressure outside the hole grows faster than inside the hole), as well as by the flow of water into the tank. Other phenomena, such as ice formation around the hole and increased LNG vaporization as the spill flows towards the water surface, are also likely to result in overall smaller LNG pools for an underwater release, and consequently, smaller hazards to the public. Therefore, the conservative approach in all scenarios considered in this study is to assume that the tank breach occurs at the waterline, as shown in Figure 7-2.

Figure 7-2: Cross-section of Typical Membrane-type LNGRV Tank



7.4 Selection of Modeling Parameters

Physical parameters, such as the LNG composition and the atmospheric conditions, affect the physical mechanisms that control events such as the formation and dispersion of an LNG vapor cloud or the size, duration and intensity of an LNG pool fire. These parameters need to be defined before the consequences of a large LNG release scenario can be quantified.

7.4.1 LNG Composition

LNG is typically composed primarily of methane (approximately 90 – 95%), with smaller fractions of heavier hydrocarbons (ethane, propane, butane, etc.). Methane is the most volatile compound in the LNG mixture, with a boiling temperature of approximately -261°F or -162°C (ethane, the next most volatile compound, has a boiling temperature of -87°C). Therefore, the vapor clouds formed from an LNG pool over water will contain primarily methane until most of the methane has evaporated and the pool has reduced to a fraction of the original volume. Similarly, in the event of an LNG pool fire, methane gas will be the primary fuel until most of the methane has been consumed and the pool has reduced to a fraction of the original volume. This study assumed LNG to be composed of 100% methane.

7.4.2 Ambient Conditions

Ambient conditions that affect the flammable vapor cloud dispersion and heat flux hazard distances include: air temperature and relative humidity, atmospheric stability, wind speed and water temperature. Other parameters that could affect the LNG pool or vapor cloud, such as waves, currently lack established modeling options and thus were not included in this study.

There are currently no regulations for offshore LNG terminals that specify which ambient conditions should be used for LNG hazard calculations. Federal regulations for land-based LNG terminals list specific requirements for the ambient conditions to be used in thermal radiation and flammable vapor dispersion hazard distance calculations. These requirements can be used as reference to select the parameters for this study. For thermal radiation calculations, 49 CFR 193.2057 states that:

- The wind speed producing the maximum exclusion distances shall be used except for wind speeds that occur less than 5% of the time, based on recorded data for the area.
- The ambient temperature and relative humidity that produce the maximum exclusion distances shall be used except for values that occur less than 5% of the time, based on recorded data for the area.

For flammable vapor dispersion calculations, 49 CFR 193.2059 states that:

- Dispersion conditions are a combination of those which result in longer predicted downwind dispersion distances than other weather conditions at the site at least 90% of the time, based on figures maintained by the National Weather Service of the U.S. Department of Commerce, or as an alternative, where the model used gives longer distances at lower wind speeds.
- Atmospheric Stability (Pasquill-Gifford Class) “F”.
- Wind speed = 2.01 meters/sec (4.5 miles per hour, or 3.9 knots).
- Wind speed reference height = 10 meters.

- Relative humidity = 50%.
- Atmospheric temperature = average in the region.

Approximately four years worth of meteorological data from buoy station No. 44025 were used to select realistic ranges of the parameters to be tested.[49] Buoy station No. 44025 is located approximately 30 nautical miles south of Islip, New York, and thus in proximity of the Project. Based on the buoy data, the ambient conditions selected for the Port Ambrose DWP location are detailed in Table 7-1.

Table 7-1: Modeling Parameters

Parameter	Vapor Dispersion Modeling	Thermal Radiation Modeling
Ambient Air Temperature	13.5°C (85°F)	-0.2°C (28°F)
Ambient Relative Humidity	50% [50]	5%
Wind Speed (at 10 m elevation)	2.0 m/s (3.9 knots)	10.0 m/s (19.4 knots)
Atmospheric Stability Class	F	-
LNG Composition	100% Methane	-
Ground Roughness	0.0002 meters	-

Note that the wind was assumed to be parallel to the vessel, from stern to bow. The wind direction – relative to the vessel – should be expected to have some effect on the dispersion of the vapor cloud. However, since the vessel will be weathervaning, the wind direction will be aligned with the vessel (or within a small angle – e.g., +/- 15 degrees) the majority of the time. Additionally, the LNG carrier represents a small obstacle to the wind flow, when compared with the size and downwind dispersion of the LNG vapor cloud.

7.4.3 LNG Pool Spreading and Vaporization Rate

The FLACS software package includes a model to calculate the spreading and vaporization of LNG (or other liquid) spills onto water (or other substrates). The FLACS pool model is based on the Shallow Water equations and has been validated against available data, as described in Section 7.2. For spills onto water, the FLACS pool model calculates the vapor generation within each grid cell according to the convective heat transfer equation:

$$M = \frac{Q}{\lambda} = \frac{h * A * (T \quad - T \quad)}{\lambda}$$

Where:

- M is the vapor generation per unit time;
- Q is the heat transfer to the pool;
- λ is the latent heat of vaporization of LNG;

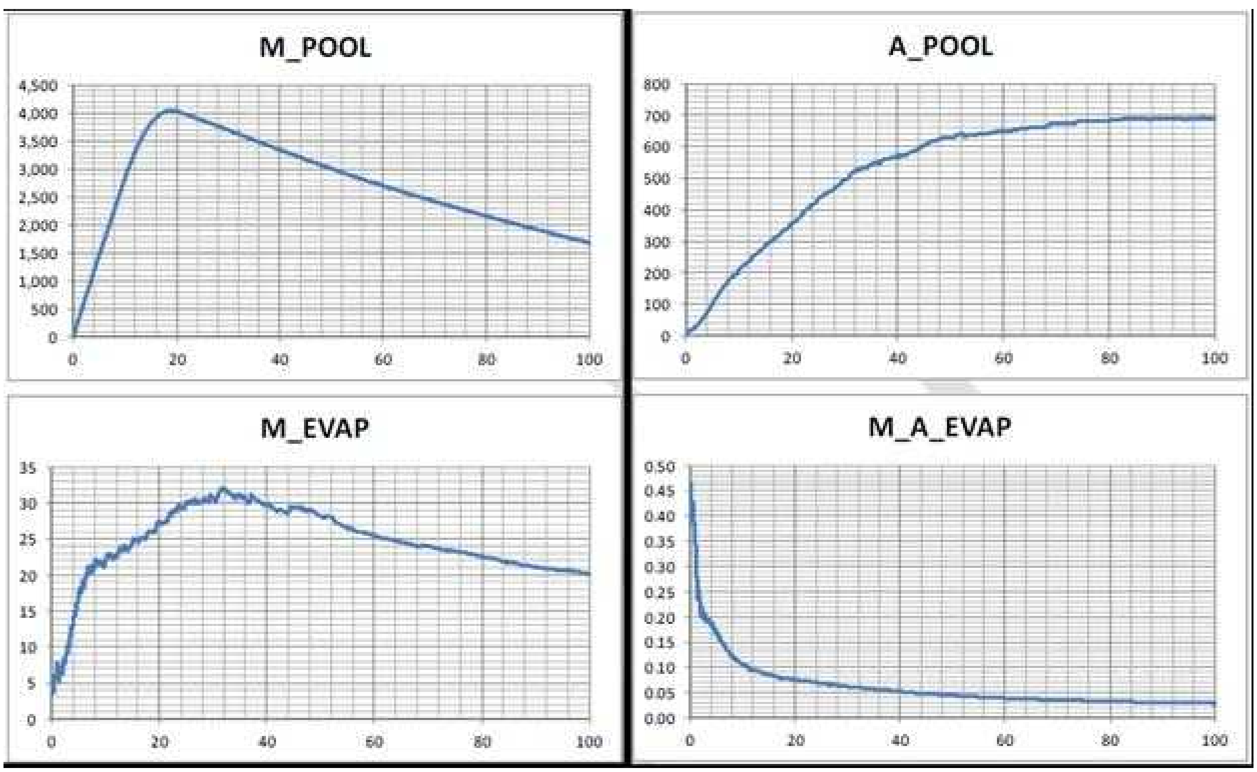
[49] The data is currently available on the National Oceanic and Atmospheric Administration (NOAA) website (http://www.ndbc.noaa.gov/station_page.php?station=44025).
[50] The effect of moisture condensation is not included in the FLACS vapor dispersion simulations

- h is the convective transfer coefficient and a function of the local Reynolds and Prandtl numbers;
- A is the surface of the grid cell;
- T_w is the temperature of the water (typically assumed equal to the ambient temperature, for these types of studies). Note that the temperature of the water is assumed to remain constant – unlike for LNG spills over solid substrates – as the convective flow within the water body continuously replaces the cold water near the surface (due to heat transfer to the LNG pool) with warmer water;
- T_p is the temperature of the pool (typically the boiling point of the spilled liquid).

The FLACS model creates a log file with relevant parameters from the pool model, which can be used to review the growth of the pool, the vaporization rate, etc. throughout a simulation. A graphical example of the data included in pool model log file is shown in Figure 7-3 (note that this example is not from one of the scenarios modeled in this study).

Based on the output from the log file for the pool model, the average LNG vaporization mass flux for the six scenarios was approximately 0.140 kg/s.

Figure 7-3: Sampling Data from FLACS Pool Model Log File (example)



7.5 Hazards Threshold Criteria

7.5.1 Flammable Vapor Dispersion

A flammable vapor cloud can only be ignited if the gas concentration is between the Lower Flammability Limit (LFL) and the Upper Flammability Limit (UFL). For methane, the LFL is 5% (by volume) and the UFL is 15% (by volume). The LFL is used as the hazard threshold for flammable vapor dispersion distances for the Phase I IRA.

7.5.2 Thermal Radiation Heat Flux

Two different thermal radiation levels are considered of interest in the evaluation of risk to the public and property. The thermal radiation thresholds are defined as follows:

- 37.5 kW/m^2: Damage to process equipment and storage tanks for unprotected exposures based on an average 10-minute exposure duration, as well immediate fatalities
- 5 kW/m^2: Permissible level for emergency operations lasting several minutes with appropriate clothing based on an average 10-minute exposed duration and onset of second degree burns based on an average 40 second exposed duration

The results of the pool fire calculations will list the distance to each of these heat fluxes estimated from the center of the pool (i.e., from the spill location).

7.6 LNG Flow from a Tank Breach

If one or more tanks of an LNGRV are breached below the liquid level, LNG will flow through the hole(s). The flow of LNG through a breach is generally modeled as flow through an orifice, driven by the hydrostatic pressure of the LNG above the hole. Assuming atmospheric pressure exists at the top of the breached tank,[51] the volumetric flow through the breach can be calculated as follows:

$$Q(t) = A C_D \sqrt{2\, g\, h(t)}$$

where:

- $Q(t)$ = volumetric flow rate at time t (m^3/s)
- A = cross-sectional area of the breach (m^2)
- C_D = discharge coefficient
- g = acceleration due to gravity (m/s^2)
- $h(t)$ = LNG hydrostatic head above the breach at time t (m)

The discharge coefficient accounts for flow reductions due to the shape of the hole; it typically ranges from approximately 0.3 (when the hole is partially obstructed) to 0.6 (for an unobstructed hole with clean edges). In this study, the spill flow rate calculations were performed using a discharge

[51] This is considered a reasonable assumption since the storage tanks operate a very small gauge pressures and are equipped with vacuum breaks, which open to the atmosphere to prevent collapsing the tank should a vacuum be formed inside.

coefficient equal to 0.6, which maximizes the LNG outflow rate, and therefore represents a conservative assumption.

The hydrostatic head of LNG above the breach varies as a function of time during the spill, decreasing as LNG flows out of the tank(s). The initial hydrostatic head was calculated to be approximately 18.8 m, based on the assumptions that the tanks are approximately 98% full and 70% of the LNG is above the waterline.

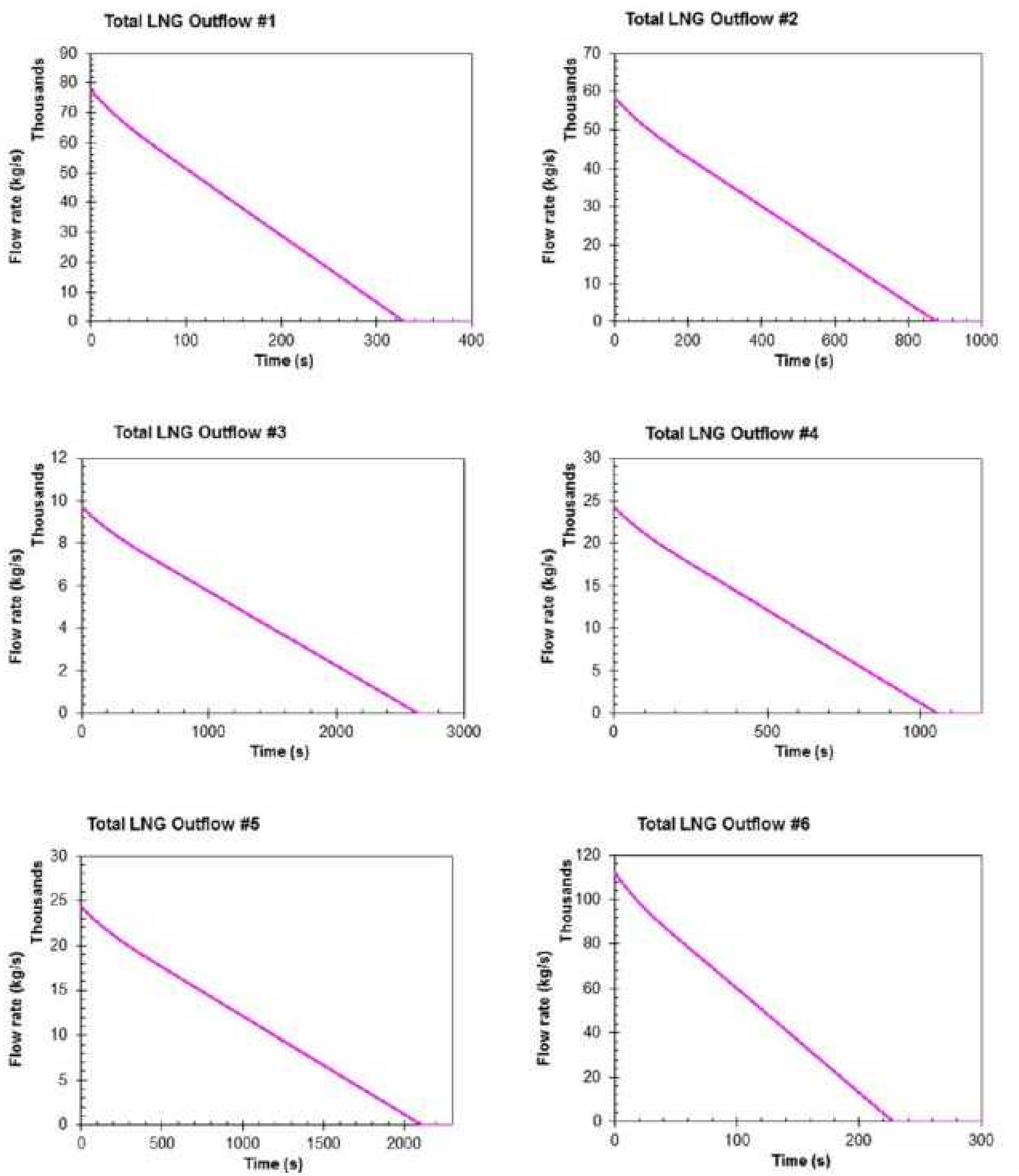
The LNG outflow model used in this study is based on calculations performed by the Federal Energy Regulatory Commission (FERC) staff,[52] modified to account for the non-uniform cross-section of the LNG storage tanks. The orifice flow model gives a time-dependent flow rate, which is the maximum at the onset of flow and decreases monotonically as the LNG inventory is depleted. A summary of the NG flow rates is given in Table 7-2 and graphically in Figure 7-4.

Table 7-2: Modeling Parameters

Scenario No.	Spilled Volume (m^3)	Maximum Flow Rate (kg/s)	Spill Duration (s)
Scenario 1	29,000	77,807	329
Scenario 2	58,000	58,355	878
Scenario 3	29,000	9,726	2,636
Scenario 4	29,000	24,315	1,054
Scenario 5	58,000	24,315	1,054
Scenario 6	29,000	112,334	228

[52] FERC, 2004.

Figure 7-4: LNG Flow Rate for Scenarios 1-6



7.7 LNG Pool Spread over Water

Due to the lighter density of LNG relative to water, LNG spilling onto water will form a pool floating on the surface. The LNG pool will spread onto the water surface due to gravity forces, while some of the LNG will evaporate due to heat transfer from the water. The balance between LNG supply (spill flow from the tank) and removal (evaporation from the pool), as well as the dynamic balance of forces (gravity, inertia and friction), determine the size of the pool as a function of time. The LNG pool evaporation flux depends on the temperature difference between water and LNG, which is assumed to remain constant over time due to convective motion within the water column, through a heat transfer coefficient which depends on both the physical properties of the fluids as well as the local relative motion between the spreading pool and the underlying water. Therefore, the evaporation rate varies in both time and space in a complex manner, yielding different results from the simpler, mass balance based calculations performed for the thermal radiation hazard analysis.

As discussed in Section 7.2, the behavior of the LNG pool on the water surface (spreading and vaporization) is calculated within FLACS, thanks to the shallow water-based pool model. A summary of the LNG pool growth for the six scenarios included in this study is shown in Figure 7-5. Note that the FLACS pool model is not constrained to assuming a circular (or semi-circular) pool shape; in fact, as shown in Figure 7-6, the pool spreads alongside the vessel and then wraps around the bow. Therefore, the pool "diameters" listed in Table 7-3 represent the diameter of an equivalent circular pool with the same area as the irregularly-shaped pool calculated by FLACS and shown in Figure 7-6.

Table 7-3: LNG Pool Spread Over Water

Scenario No.	Spilled Volume (m^3)	Maximum Pool Diameter (meters) (measured from the center of the pool)
Scenario 1	29,000	533
Scenario 2	58,000	556
Scenario 3	29,000	268
Scenario 4	29,000	382
Scenario 5	58,000	410
Scenario 6	29,000	541

Figure 7-5: LNG Pool Size vs. Time for Scenarios 1-6

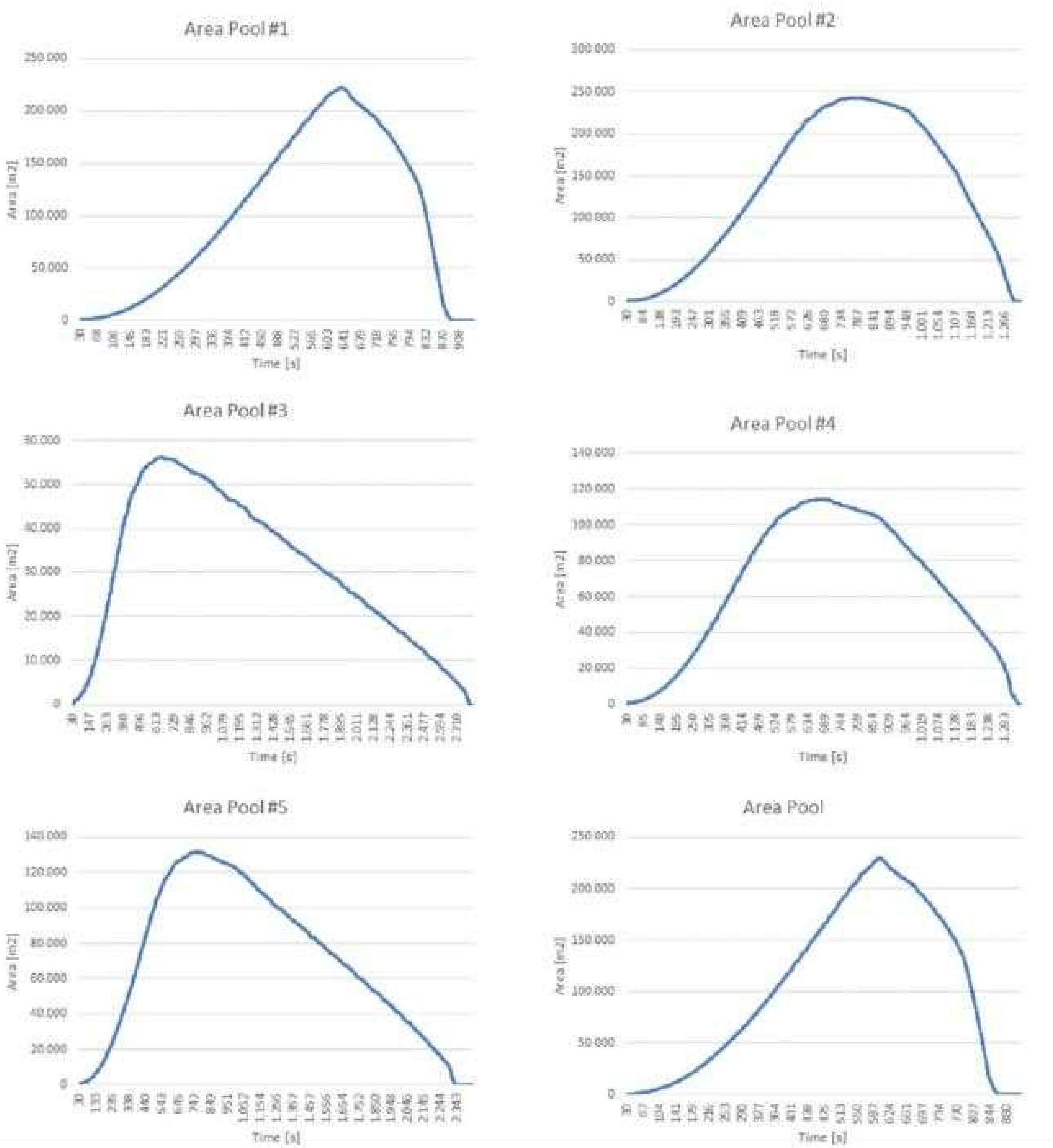
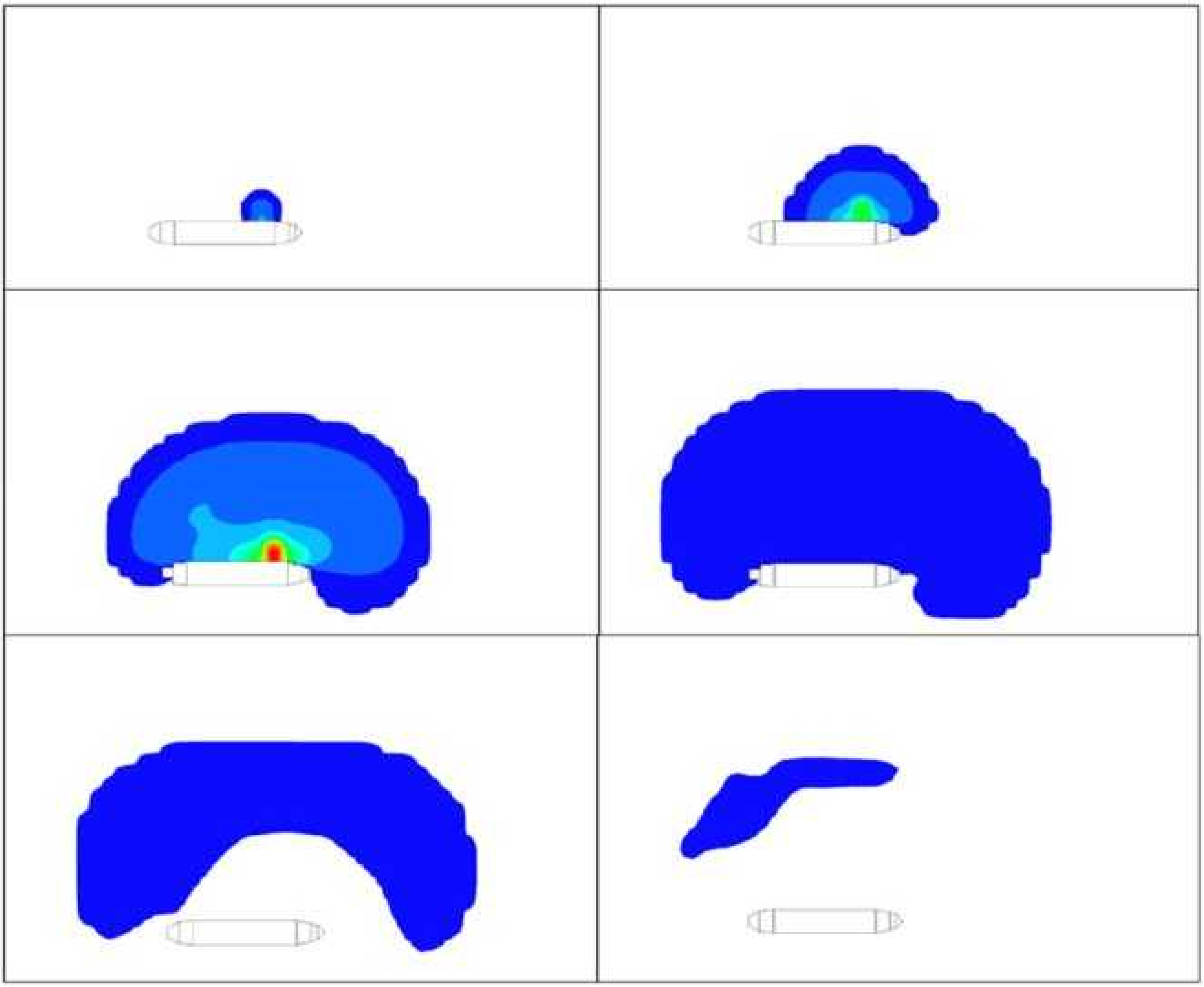


Figure 7-6: Snapshot of the LNG Pool Growth at Different Times for Scenarios 1



7.8 LNG Pool Fire Modeling

An LNG spill scenario can result in a pool fire when an LNG pool is formed onto the water surface and the vapors emanating from the pool are ignited close to the pool. The pool fire is fueled by the LNG that evaporates from the pool, as a result of heat transfer from the water underneath and the radiation from the fire above. The size of the LNG pool, and therefore the size of the pool fire, change with time as the pool spreads and recedes (see previous section). Therefore, the thermal radiation heat flux to a stationary target is a function of time, increasing when the pool expands towards the target and decreasing when the pool recedes towards the vessel. A conservative estimate of the radiation heat flux to a stationary target can be obtained by assuming the pool to be at equilibrium relative to the average spill rate – that is, the pool size is assumed to be such that the vaporization rate (under burning conditions) is equal to the mass added to the pool by the LNG spill.

With the exception of the LNGRV, there are no other structures or geometric obstacles expected to be in proximity of the proposed DWP that could affect the growth of a pool fire or shield potential targets from the fire's radiation. Therefore, CFD models of the pool fire are not deemed necessary and simpler models can be used to calculate the thermal radiation hazard distances.

A very common model for these scenarios is the solid flame model[53]: the fire is represented as a cylinder, whose base is equal to the area of the pool of fuel and whose height is determined from semi-empirical correlations. The radiation from the cylinder to a target depends on the emissive power of the fire surface, the transmissivity of the atmosphere, and the position of the target relative to the fire (the "view factor"). The hazard distances for this study were calculated according to the recommendations published by Sandia[54] in 2011 following the analysis of their large-scale LNG pool fire tests, as summarized in Table 7-4.

Table 7-4: LNG Pool Fire Modeling Parameters (other than ambient conditions)

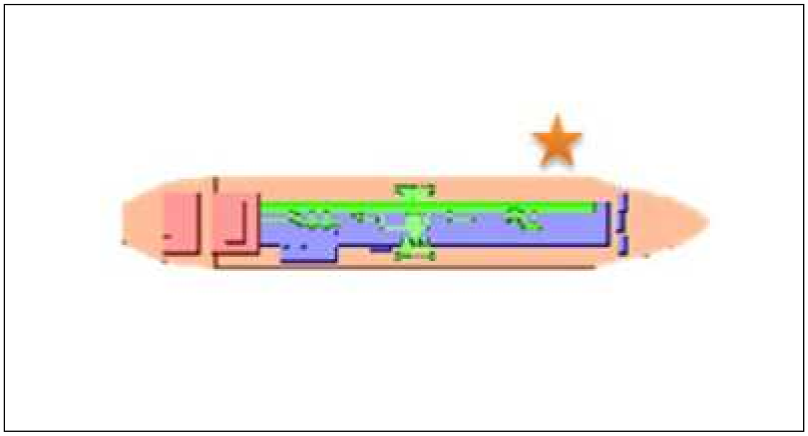
Parameter	Value
Discharge Coefficient	0.6
Burning Rate	3.5×10^{-4} m/s
Surface Emissive Power	286 kW/m^2
Atmospheric Transmissivity	Wayne[55] formula
Flame Height Correlation	SNL correlation
Flame Tilt Correlation	AGA[56] Model

7.9 Flammable Vapor Dispersion Results

The dispersion of LNG vapors from a spill on water were calculated using the FLACS CFD model and the parameters described earlier. A simple model of the LNG carrier is included in the FLACS 3D model for these simulations. According to the proposed plans, the unloading vessels will be moored to the buoy and therefore will be able to weathervane while at berth. Therefore, in the simulations the vessel is assumed to be aligned with the wind direction. The tank breach is assumed to occur at the waterline, at midship on the port side of the LNG carrier, as shown in Figure 7-7.

[53] Beyler, 2002.
[54] A. Luketa, Recommendations on the Prediction of Thermal Hazard Distances from Large Liquefied Natural Gas Pool Fires on Water for Solid Flame Models, SAND2011-9415 (2011).
[55] Wayne, D.F. "An Economical Forum for Calculating Atmospheric Infrared Transmissivities." *J. Loss Prev. Process Ind.*, 1991: 85-92
[56] "LNG Safety Research Program," *Report IS 3-1,* American Gas Association (1974).

Figure 7-7: LNG Pool Location (port side of the LNGRV)



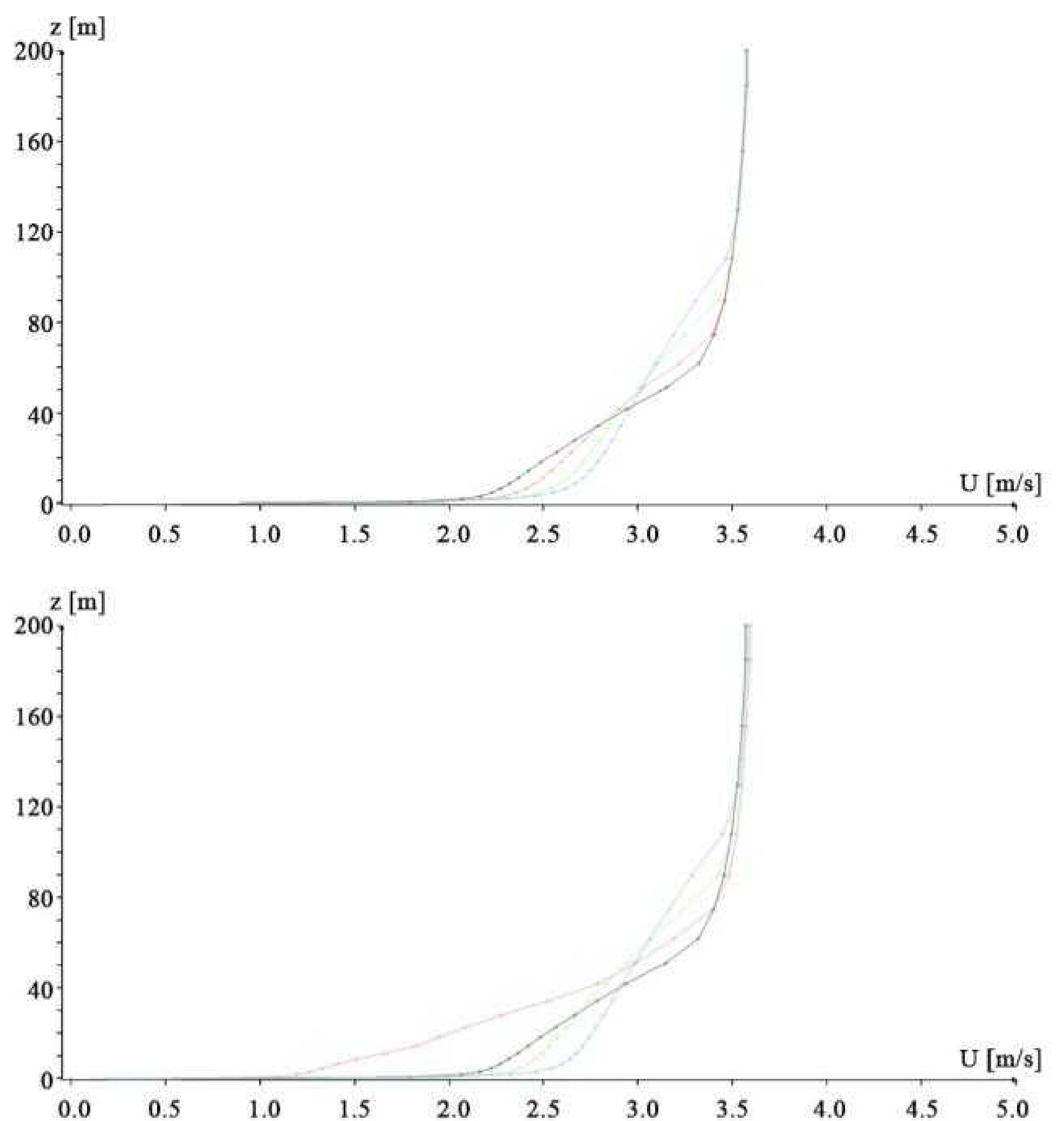
Given the single-block, Cartesian mesh adopted in FLACS, two different sets of computational domains were used in the simulations:

1. A small domain focused on resolving the LNG pool spreading and vaporization was used to calculate the maximum area of the pool. The simulation domain extends from 500 m upwind of the spill to 800 m downwind, spanning 700 m on the port side of the ship (the side of the spill) and 500 m on the starboard side of the ship. The ceiling for the simulation domain is set to 50 m. The horizontal grid resolution ranges from 5 m in the area of the spill to 10 m downwind; the vertical resolution is 1 m near water level and stretched upwards.
2. A domain focused on resolving the LNG pool spreading and vaporization was used, as well as the dispersion of the LNG vapor cloud. The simulation domain extends from 2 km upwind of the spill to 5 km downwind, spanning 3 km crosswind on both sides of the ship. The ceiling for the simulation domain is set to 200 m. The horizontal grid resolution ranges from 2 m in the area of the spill to 50 m downwind; the vertical resolution is 1 m near water level and stretched upwards.

The computational grid dimensions were selected based on the FLACS validation work previously performed by GexCon for LNG vapor dispersion, taking also into account the available computational resources and project schedule.

An atmospheric boundary layer wind profile is imposed on the upwind, cross-wind and top boundaries of the domain. The downwind boundary is left open. The velocity and turbulence profiles are determined using the specified velocity ambient conditions (see Table 7-1) and the Monin-Obukhov equations, which are built into the FLACS model. Figure 7-8 shows the wind velocity profile at different locations along the simulation domain, prior to the LNG spill. The horizontal axis represents the wind velocity (wind blows along the X direction in the simulation domain), and the vertical axis represents the elevation above the water surface. The off-center locations (2 km crosswind from the pool mid-plane), show that the velocity profiles remain consistent with the imposed boundary conditions throughout the domain (there is no effect from the tanker at those locations). The plots along the pool mid-plane show the effect of the LNG tanker on the atmospheric profile (wind speed is approximately zero (0) up to the elevation of the tanker deck).

Figure 7-8: Vertical Profile of Wind Velocity at Different Downwind Locations for Scenario 1 (top: along pool centerline; bottom: 2 km off-center).



7.9.1 Scenario 1 – Vapor Cloud Dispersion Results

Snapshots from the simulation of the flammable vapor cloud dispersion for Scenario 1 are shown in Figure 7-9 through Figure 7-11. The plots show the LNG pool on the left, color-coded according to the thickness of the liquid, and the footprint of the vapor cloud at concentrations equal to or greater than LFL (5% methane by volume), color-coded according to the gas concentration at water level. The sequence of images shows the initial growth of the pool and of the flammable cloud, followed by the downwind drift of the cloud and its progressive dissipation once the LNG pool is depleted.

The maximum distance reached by the flammable vapors in Scenario 1 is approximately 2,800 m from the location of the spill. The maximum distance to LFL is reached approximately 22 minutes after the tank is first breached.

Figure 7-9: Snapshot of the LNG Vapor Cloud for Scenario 1 (at approximately 11 minutes after tank breach)

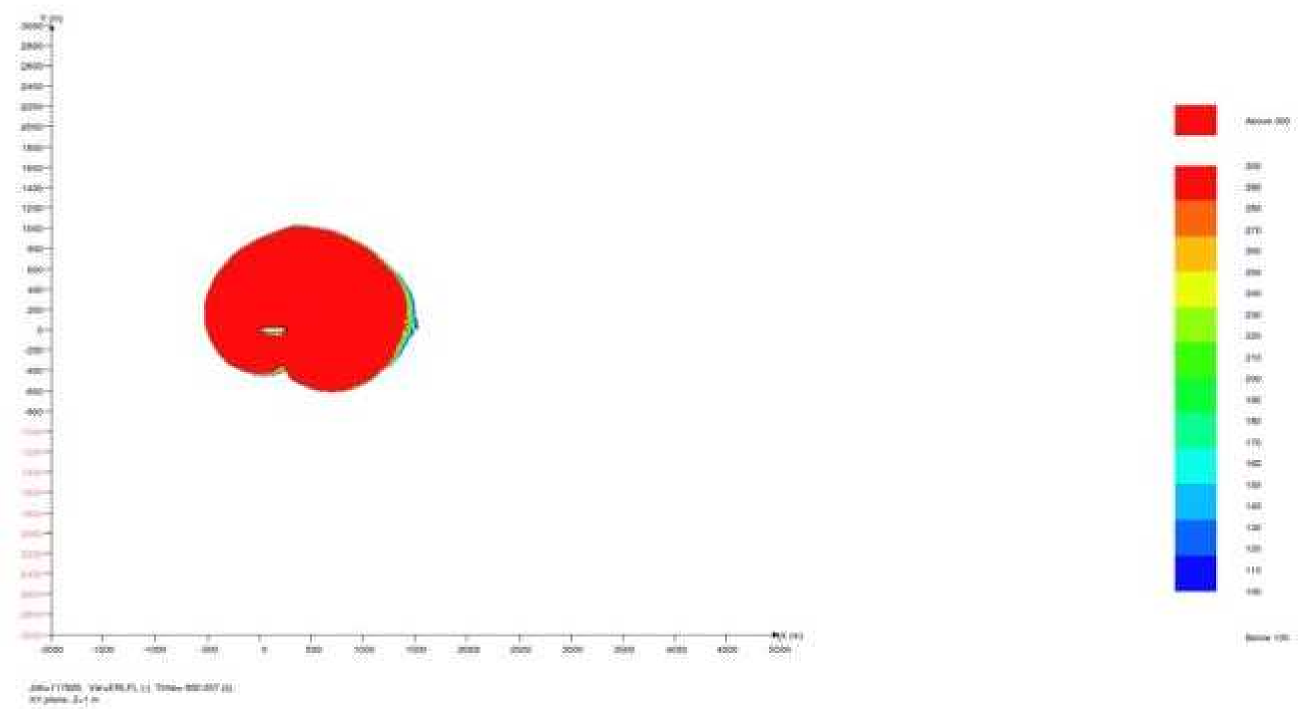


Figure 7-10: Snapshot of the LNG Vapor Cloud for Scenario 1 (at approximately 22 minutes after tank breach)

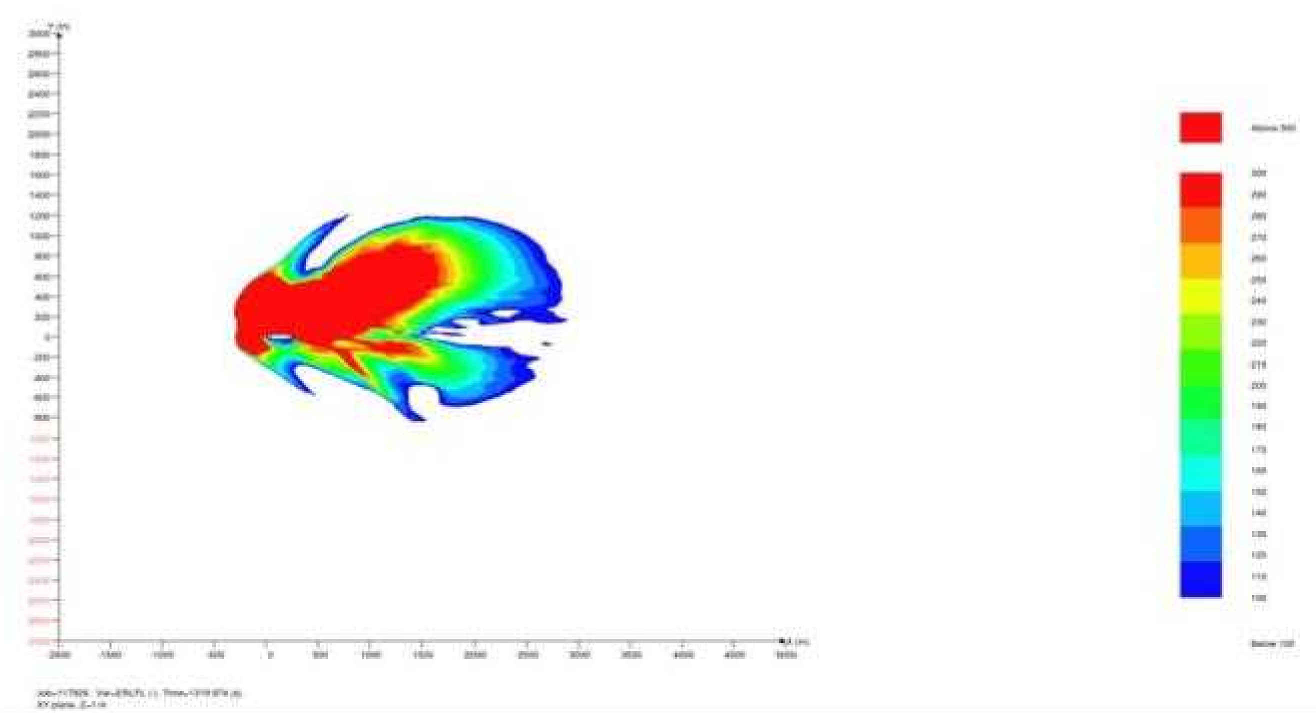
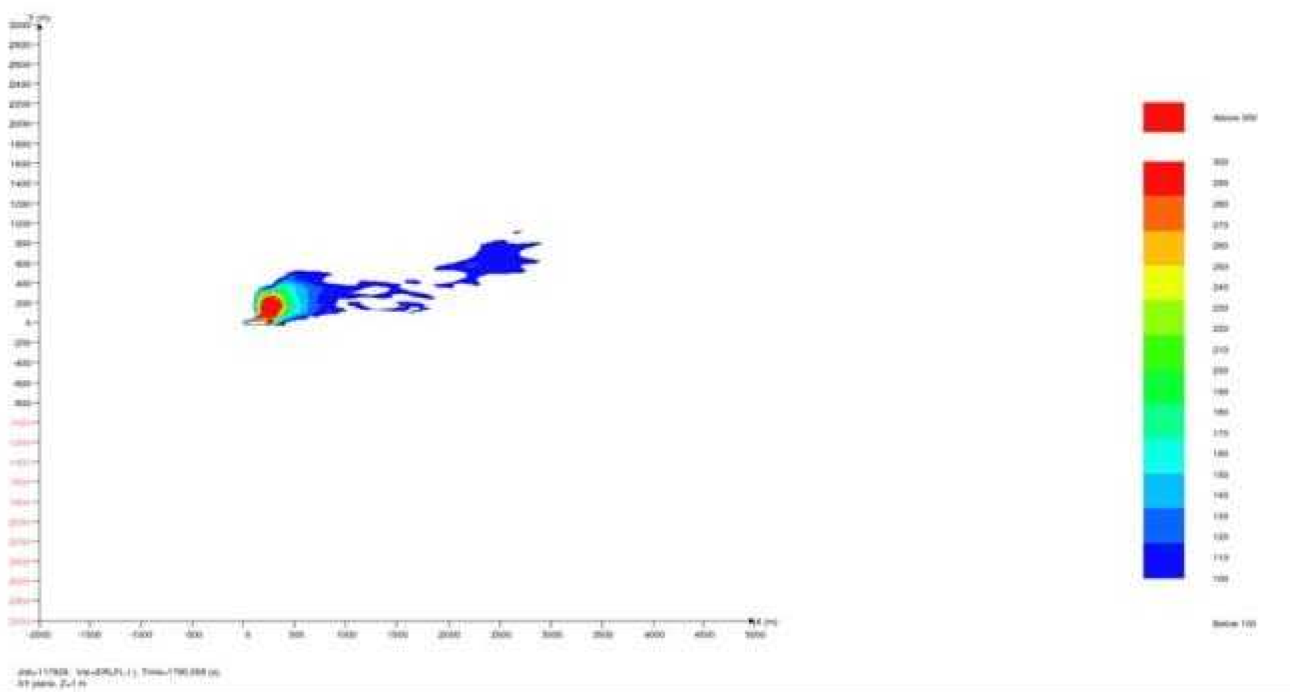


Figure 7-11: Snapshot of the LNG Vapor Cloud for Scenario 1 (at approximately 30 minutes after tank breach)



7.9.2 Scenario 2 – Vapor Cloud Dispersion Results

Snapshots from the simulation of the flammable vapor cloud dispersion for Scenario 2 are shown in Figure 7-12 through Figure 7-14. The plots show the LNG pool on the left, color-coded according to the thickness of the liquid, and the footprint of the vapor cloud at concentrations equal to or greater than LFL (5% methane by volume), color-coded according to the gas concentration at water level. The sequence of images shows the initial growth of the pool and of the flammable cloud, followed by the downwind drift of the cloud and its progressive dissipation once the LNG pool is depleted.

The maximum distance reached by the flammable vapors in Scenario 2 is approximately 3,550 m from the location of the spill. The maximum distance to LFL is reached approximately 27 minutes after the tank is first breached.

Figure 7-12: Snapshot of the LNG Vapor Cloud for Scenario 2 (at approximately 13.5 minutes after tank breach)

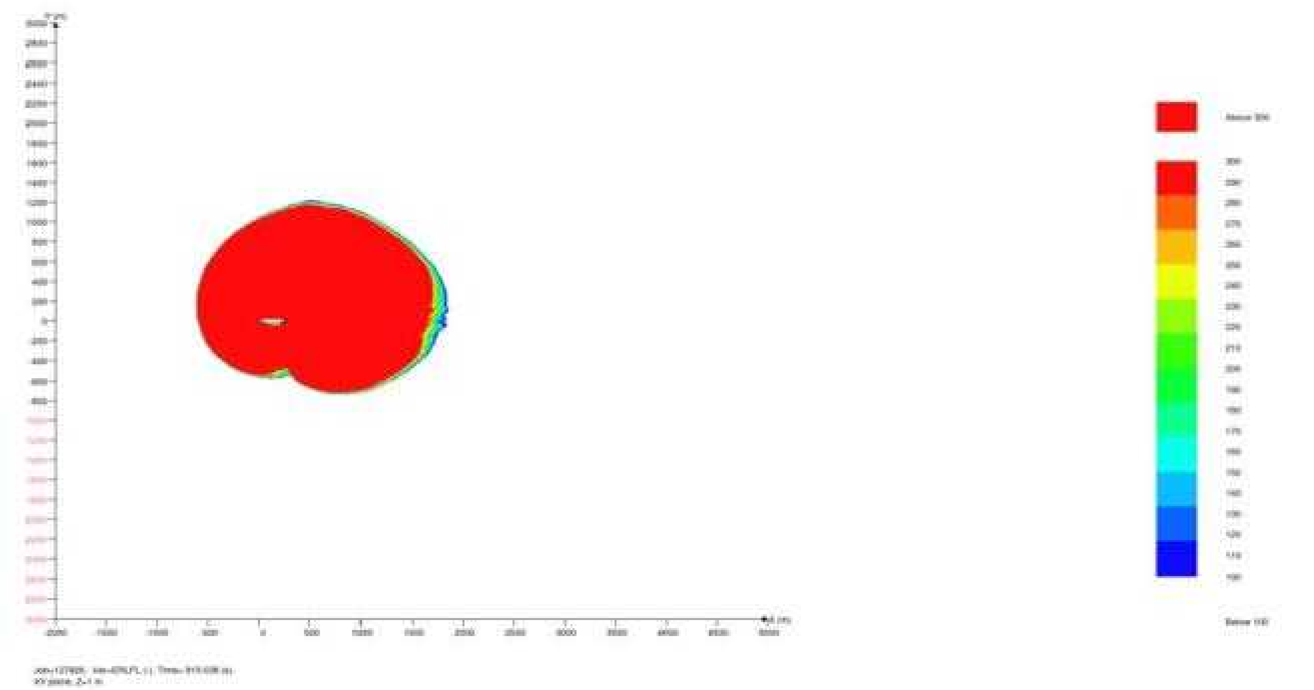


Figure 7-13: Snapshot of the LNG Vapor Cloud for Scenario 2 (at approximately 27 minutes after tank breach)

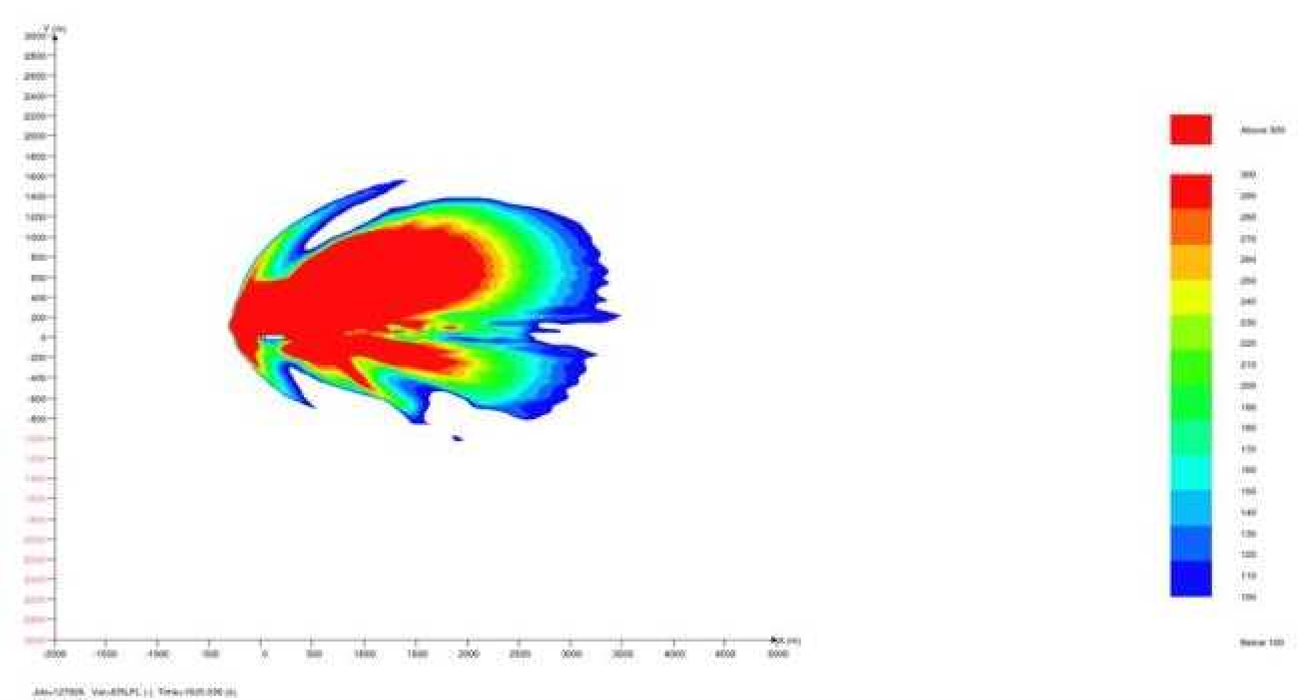
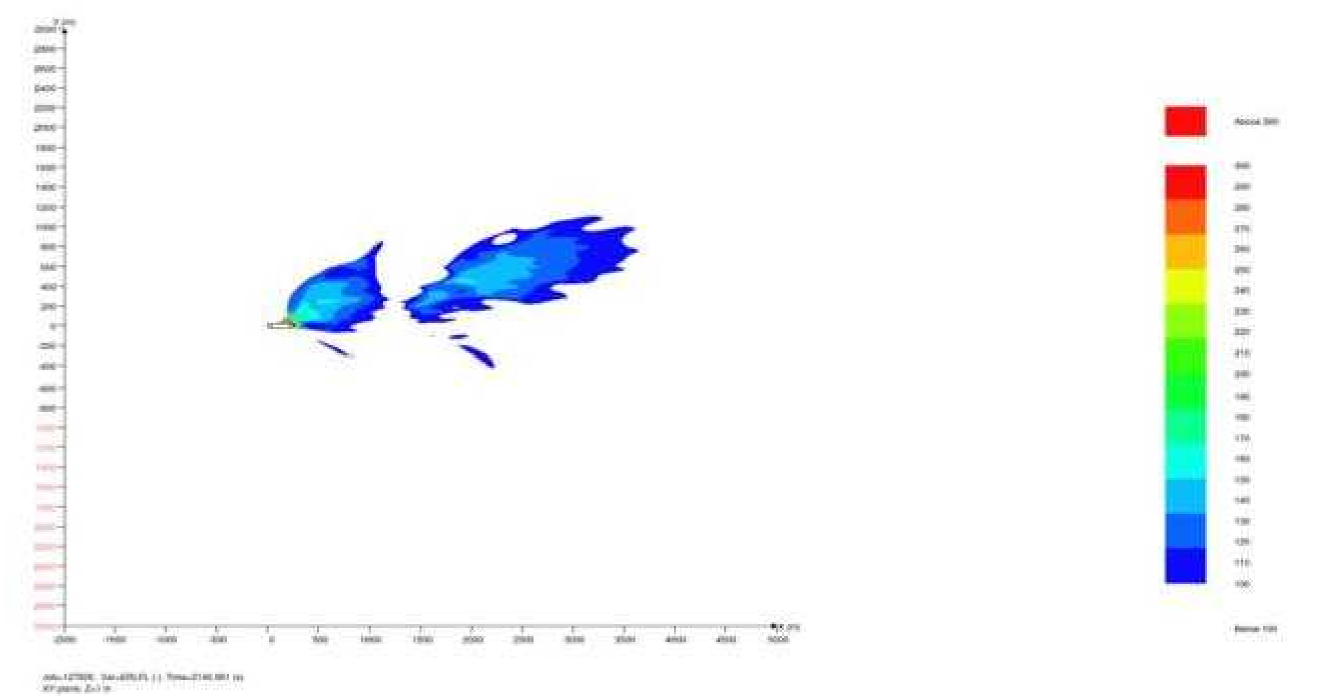


Figure 7-14: Snapshot of the LNG Vapor Cloud for Scenario 2 (at approximately 35 minutes after tank breach)



7.9.3 Scenario 3 – Vapor Cloud Dispersion Results

Snapshots from the simulation of the flammable vapor cloud dispersion for Scenario 3 are shown in Figure 7-15 through Figure 7-17. The plots show the LNG pool on the left, color-coded according to the thickness of the liquid, and the footprint of the vapor cloud at concentrations equal to or greater than LFL (5% methane by volume), color-coded according to the gas concentration at water level. The sequence of images shows the initial growth of the pool and of the flammable cloud, followed by the downwind drift of the cloud and its progressive dissipation once the LNG pool is depleted.

The maximum distance reached by the flammable vapors in Scenario 3 is approximately 2,350 m from the location of the spill. The maximum distance to LFL is reached approximately 27 minutes after the tank is first breached.

Figure 7-15: Snapshot of the LNG Vapor Cloud for Scenario 3 (at approximately 13.5 minutes after tank breach)

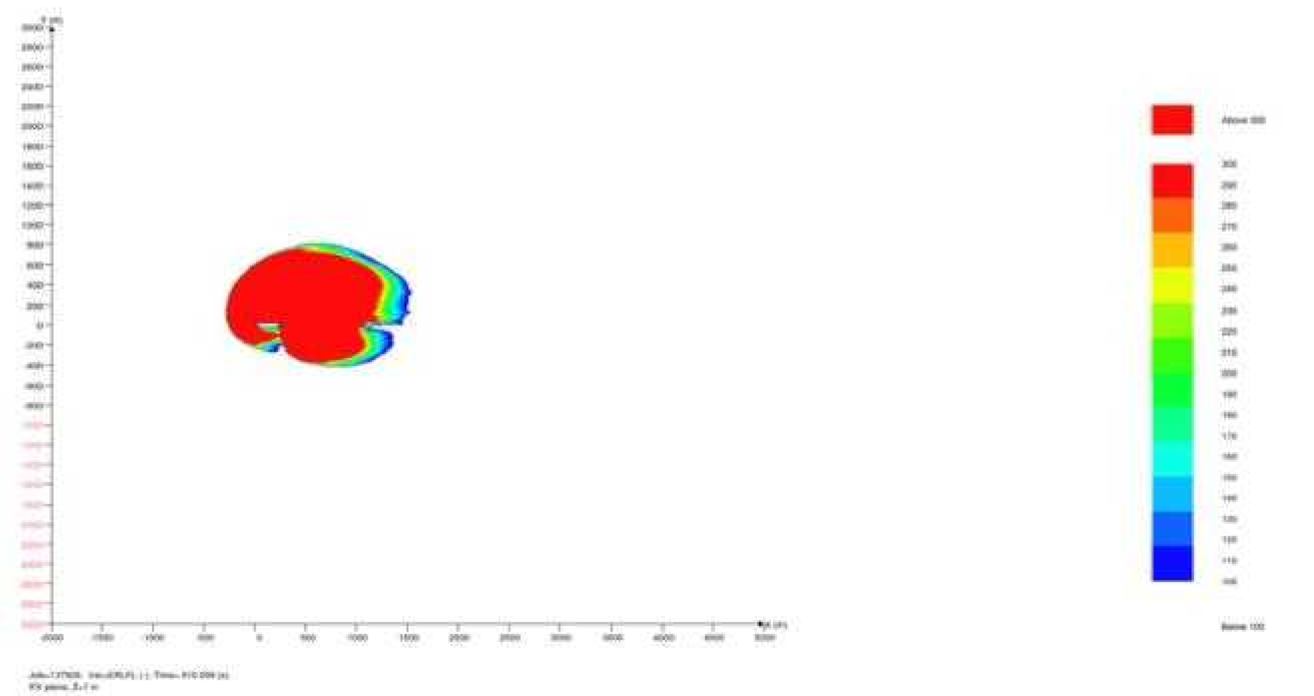


Figure 7-16: Snapshot of the LNG Vapor Cloud for Scenario 3 (at approximately 27 minutes after tank breach)

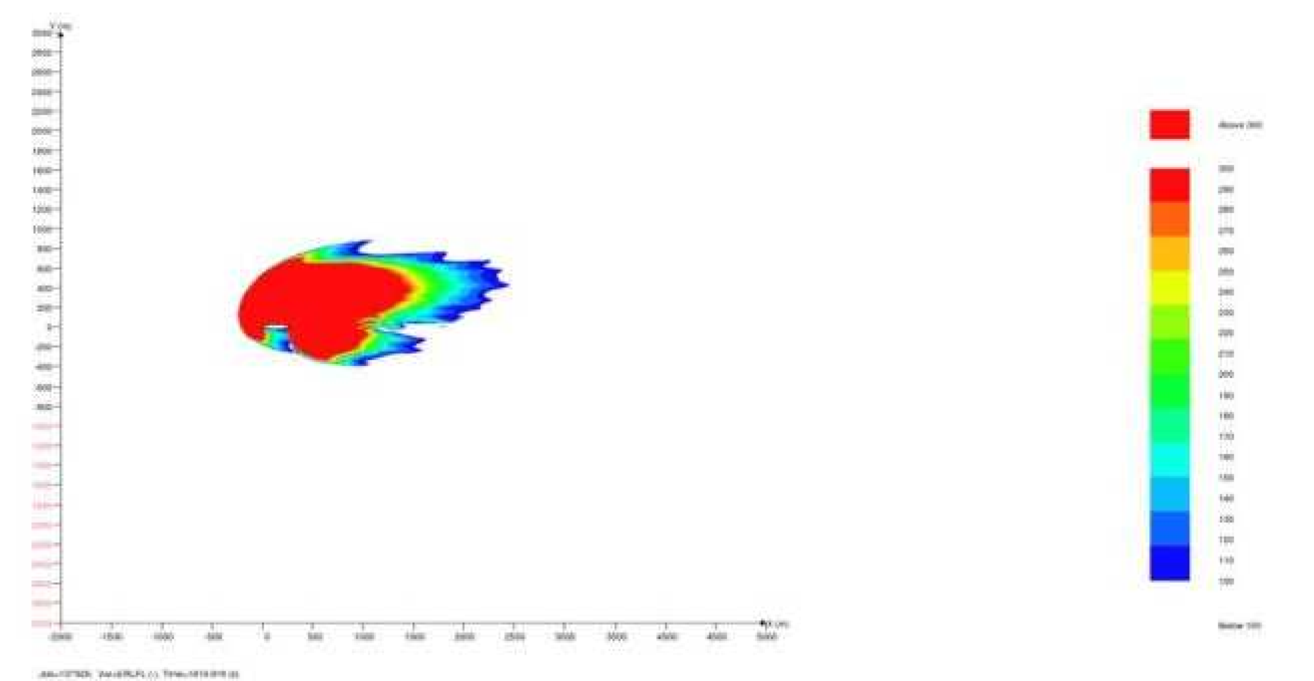
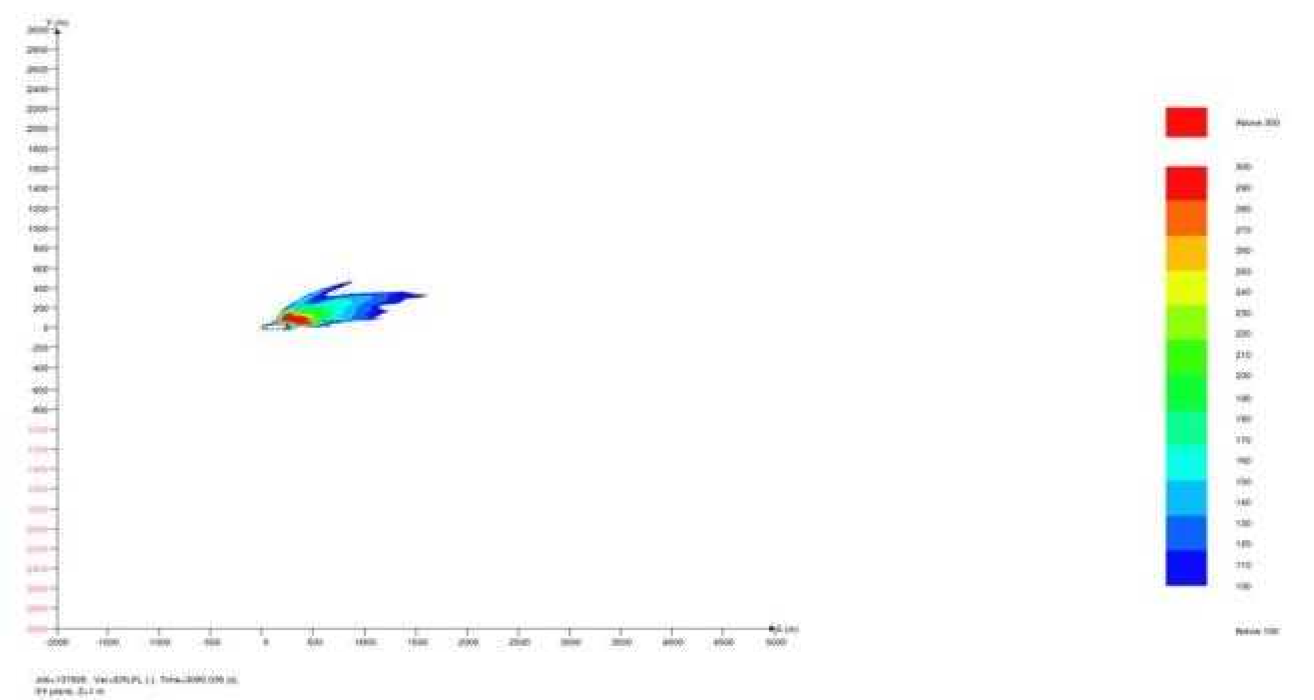


Figure 7-17: Snapshot of the LNG Vapor Cloud for Scenario 3 (at approximately 51 minutes after tank breach)



7.9.4 Scenario 4 – Vapor Cloud Dispersion Results

Snapshots from the simulation of the flammable vapor cloud dispersion for Scenario 4 are shown in Figure 7-18 through Figure 7-20. The plots show the LNG pool on the left, color-coded according to the thickness of the liquid, and the footprint of the vapor cloud at concentrations equal to or greater than LFL (5% methane by volume), color-coded according to the gas concentration at water level. The sequence of images shows the initial growth of the pool and of the flammable cloud, followed by the downwind drift of the cloud and its progressive dissipation once the LNG pool is depleted.

The maximum distance reached by the flammable vapors in Scenario 4 is approximately 2,800 m from the location of the spill. The maximum distance to LFL is reached approximately 29 minutes after the tank is first breached.

Figure 7-18: Snapshot of the LNG Vapor Cloud for Scenario 4 (at approximately 14.5 minutes after tank breach)

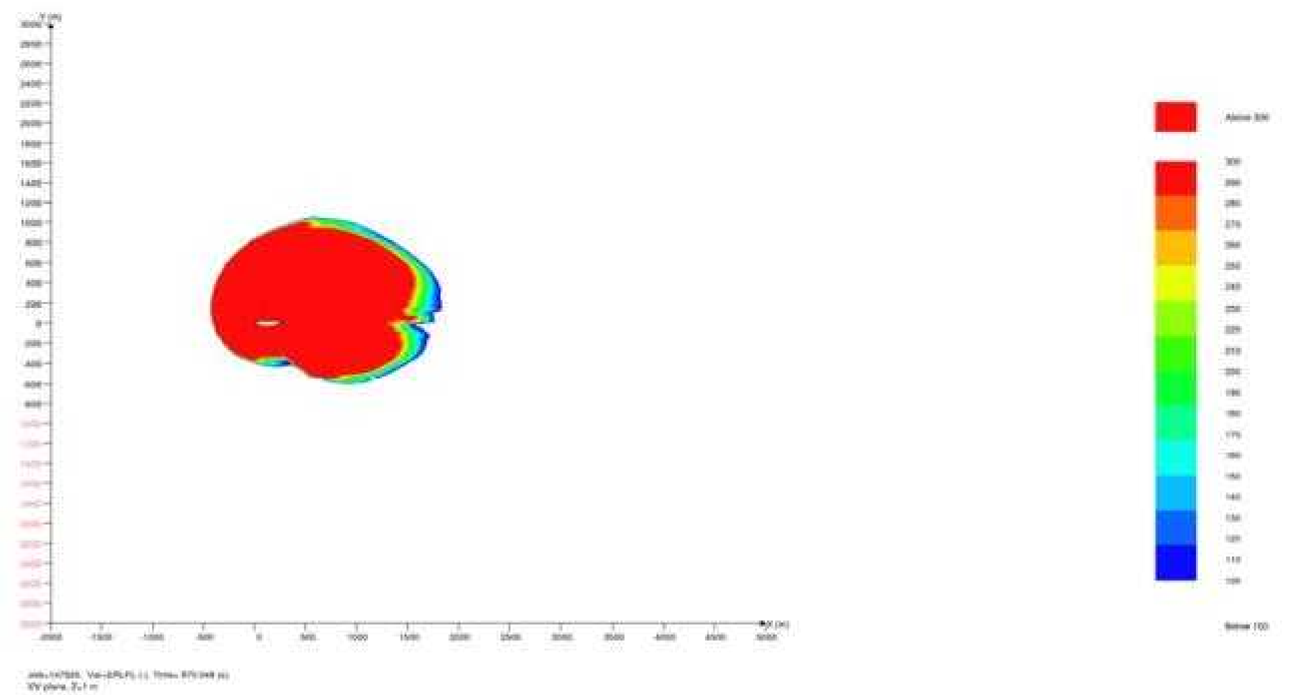


Figure 7-19: Snapshot of the LNG Vapor Cloud for Scenario 4 (at approximately 29 minutes after tank breach)

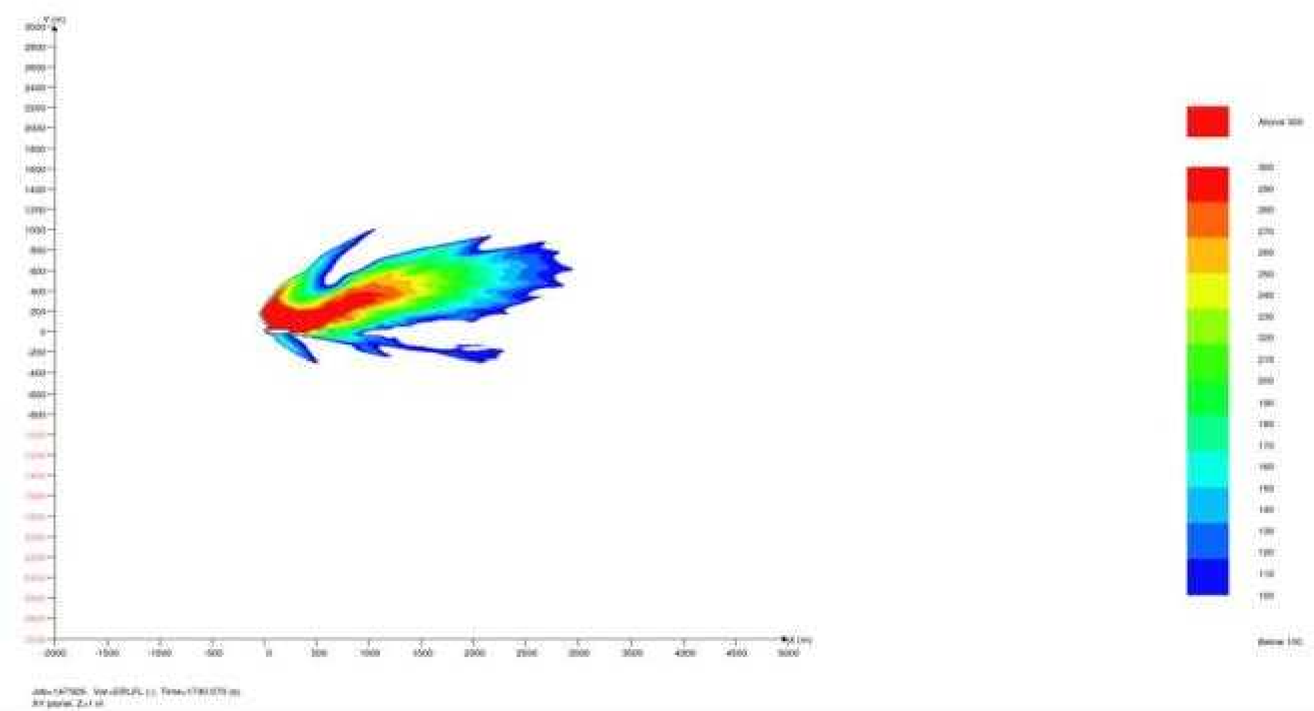
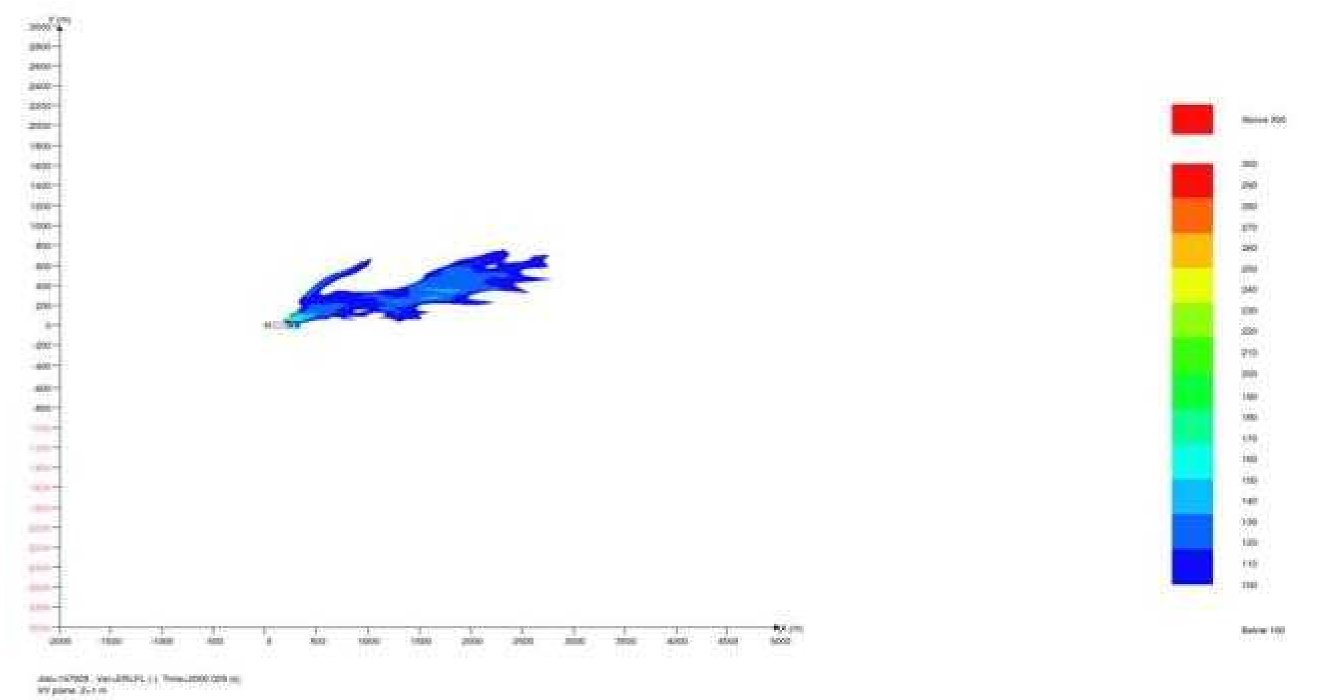


Figure 7-20: Snapshot of the LNG Vapor Cloud for Scenario 4 (at approximately 33 minutes after tank breach)



7.9.5 Scenario 5 – Vapor Cloud Dispersion Results

Snapshots from the simulation of the flammable vapor cloud dispersion for Scenario 5 are shown in Figure 7-21 through Figure 7-23. The plots show the LNG pool on the left, color-coded according to the thickness of the liquid, and the footprint of the vapor cloud at concentrations equal to or greater than LFL (5% methane by volume), color-coded according to the gas concentration at water level. The sequence of images shows the initial growth of the pool and of the flammable cloud, followed by the downwind drift of the cloud and its progressive dissipation once the LNG pool is depleted.

The maximum distance reached by the flammable vapors in Scenario 5 is approximately 3,150 m from the location of the spill. The maximum distance to LFL is reached approximately 33 minutes after the tank is first breached.

Figure 7-21: Snapshot of the LNG Vapor Cloud for Scenario 5 (at approximately 16.5 minutes after tank breach)

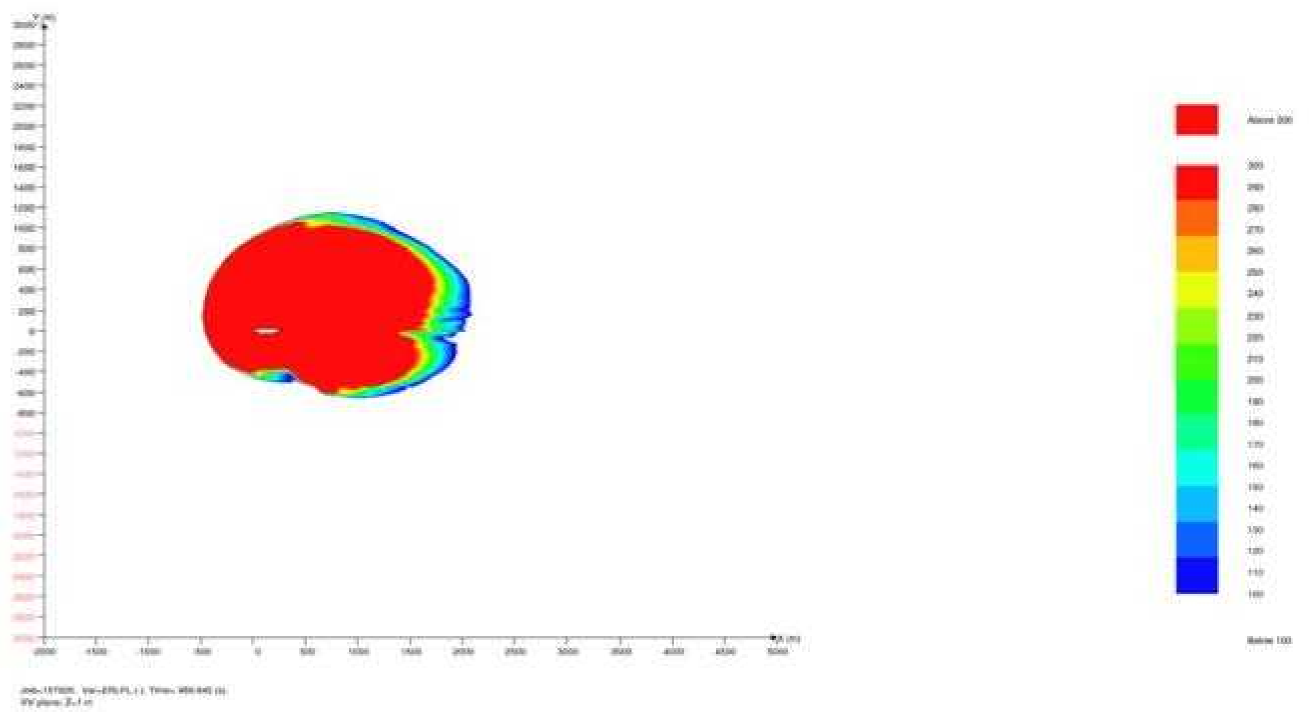


Figure 7-22: Snapshot of the LNG Vapor Cloud for Scenario 5 (at approximately 33 minutes after tank breach)

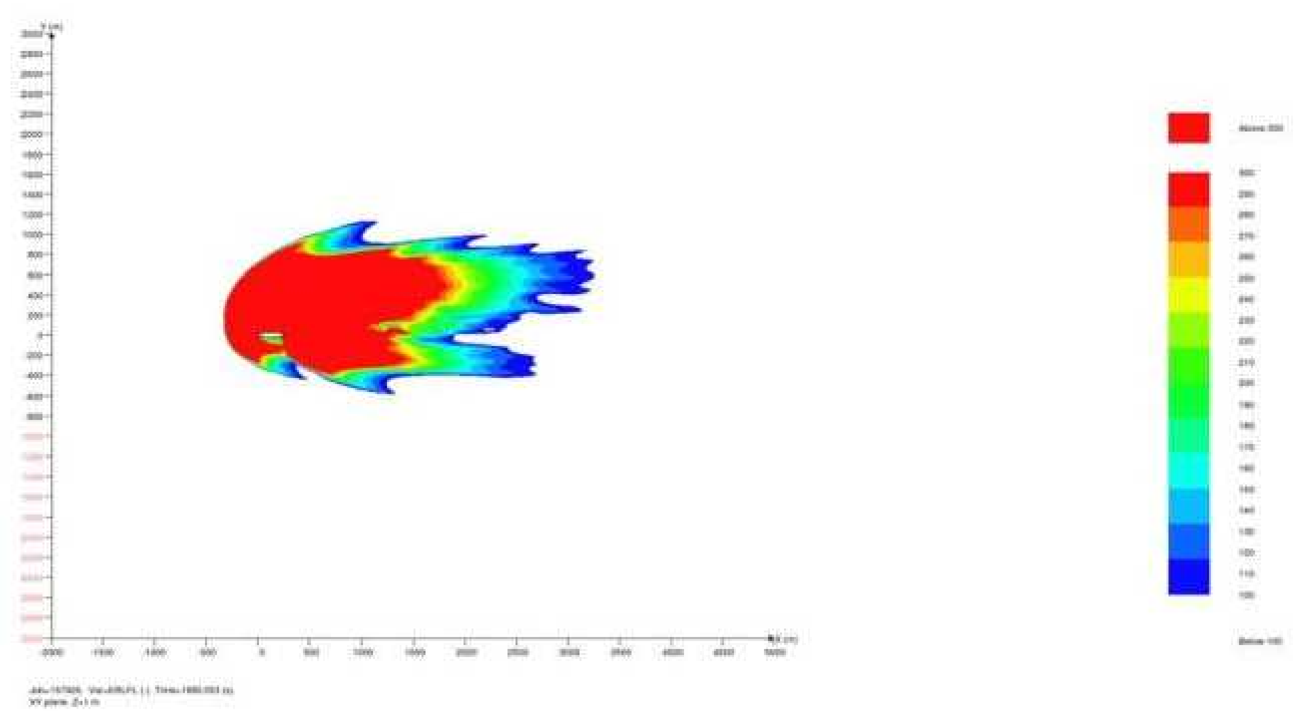
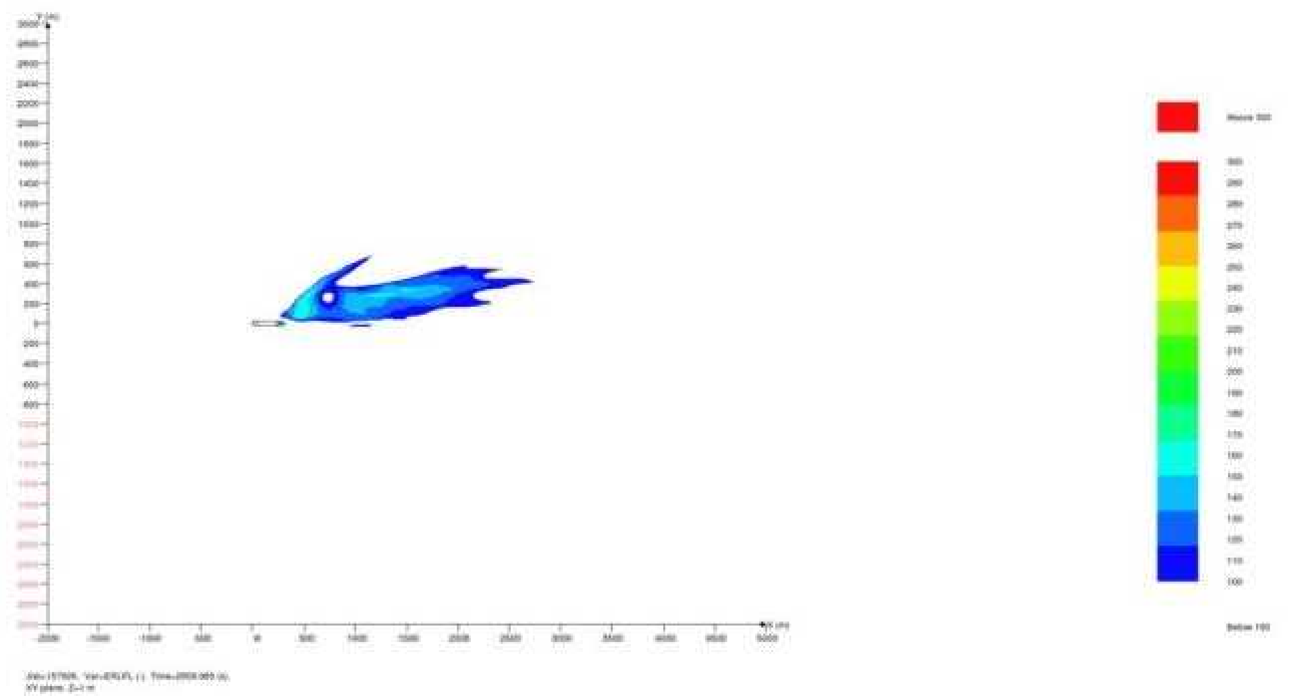


Figure 7-23: Snapshot of the LNG Vapor Cloud for Scenario 5 (at approximately 48 minutes after tank breach)



7.9.6 Scenario 6 – Vapor Cloud Dispersion Results

Snapshots from the simulation of the flammable vapor cloud dispersion for Scenario 6 are shown in Figure 7-24 through Figure 7-26. The plots show the LNG pool on the left, color-coded according to the thickness of the liquid, and the footprint of the vapor cloud at concentrations equal to or greater than LFL (5% methane by volume), color-coded according to the gas concentration at water level. The sequence of images shows the initial growth of the pool and of the flammable cloud, followed by the downwind drift of the cloud and its progressive dissipation once the LNG pool is depleted.

The maximum distance reached by the flammable vapors in Scenario 6 is approximately 2,750 m from the location of the spill. The maximum distance to LFL is reached approximately 22 minutes after the tank is first breached.

Figure 7-24: Snapshot of the LNG Vapor Cloud for Scenario 6 (at approximately 11 minutes after tank breach)

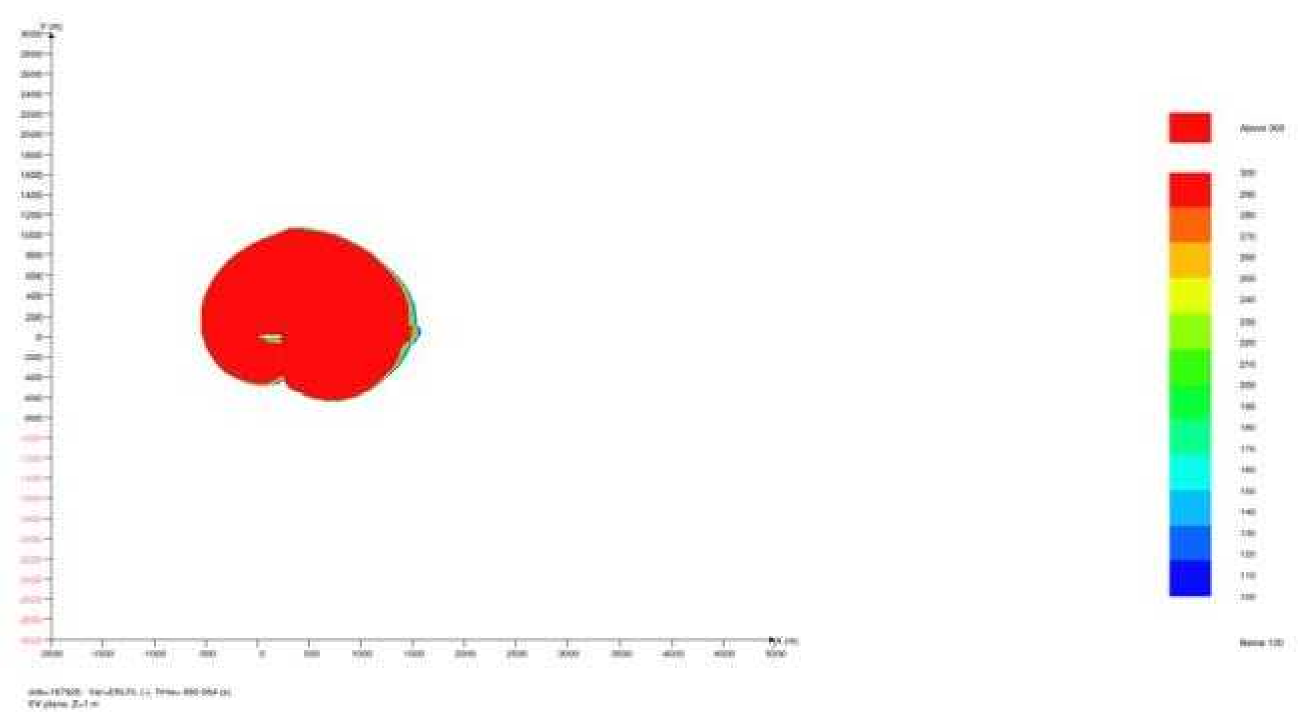


Figure 7-25: Snapshot of the LNG Vapor Cloud for Scenario 6 (at approximately 22 minutes after tank breach)

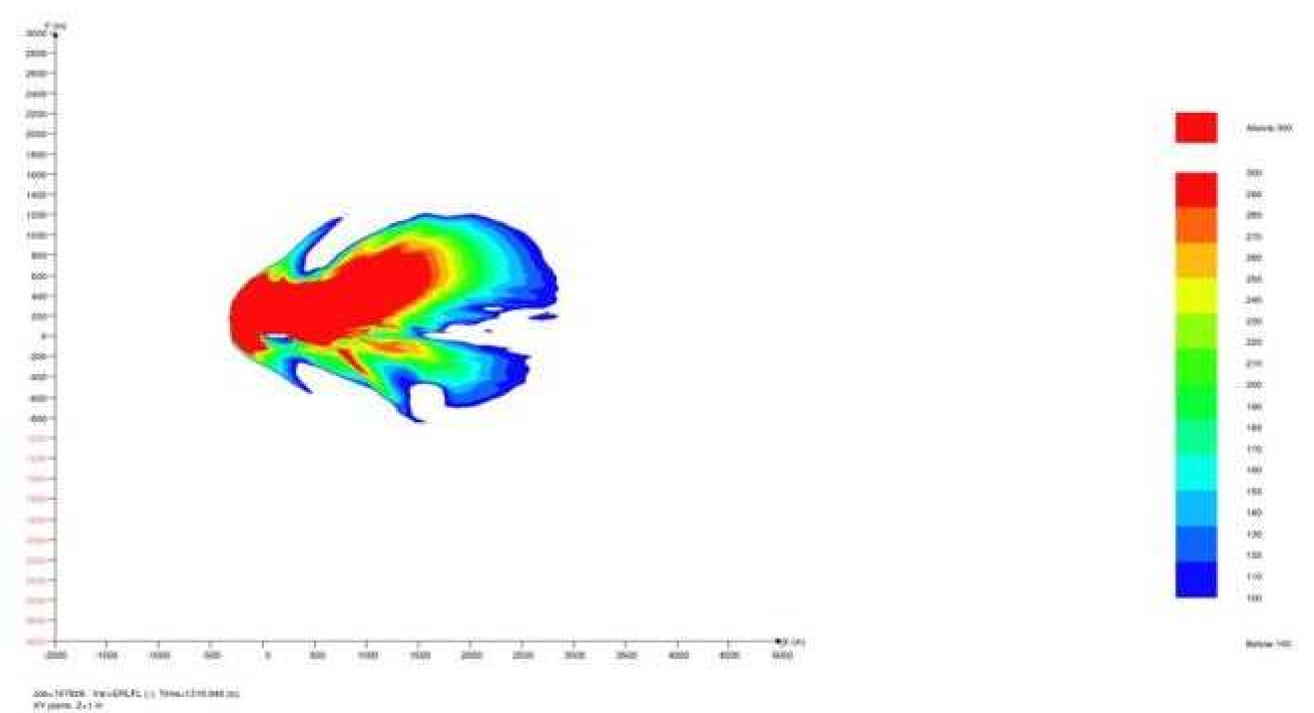
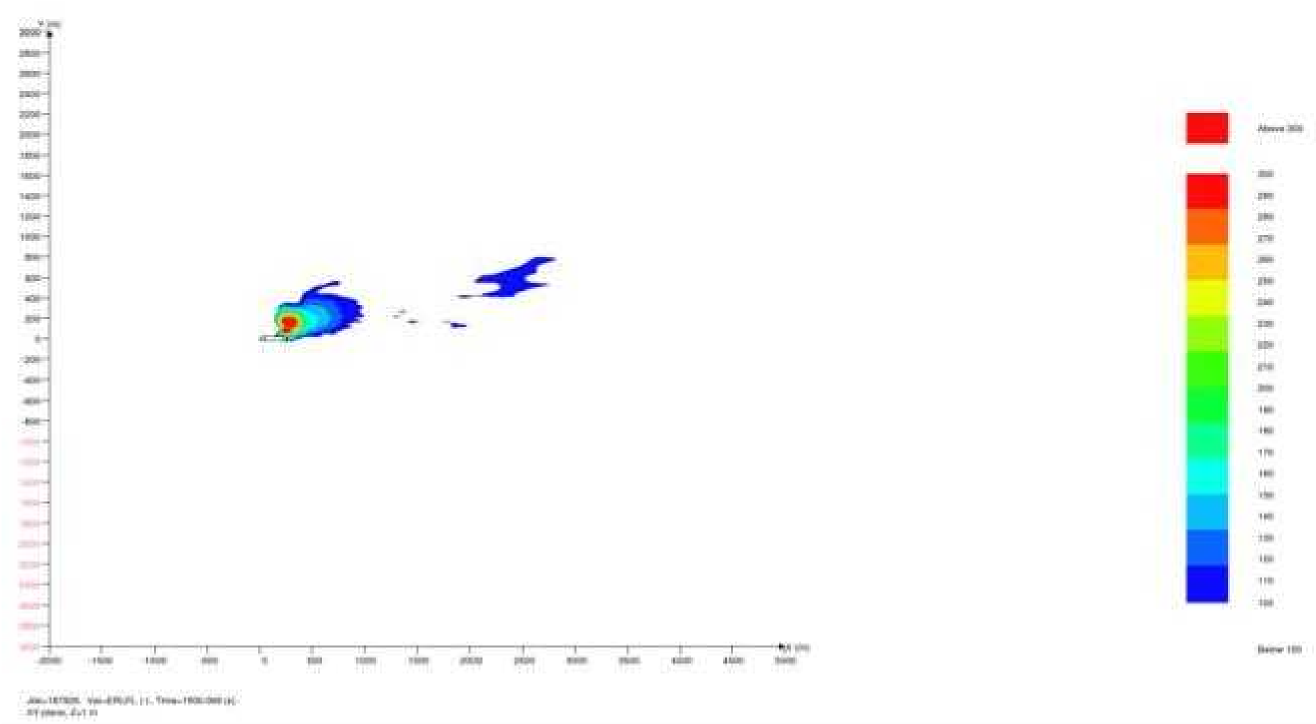


Figure 7-26: Snapshot of the LNG Vapor Cloud for Scenario 6 (at approximately 30 minutes after tank breach)



7.10 Thermal Radiation from LNG Pool Fire Results

The hazard distances to the selected heat flux levels (37.5, 25 and 5 kW/m2) calculated using the equilibrium pool diameters as specified in Section 7.8 are listed in Table 7-5. The thermal radiation hazard distances are measured from the center of the LNG pool.

Table 7-5: Radiation Heat Flux Results for Scenarios 1-6

Scenario No.	Diameter (m)	Distance (m) to 37.5 kW/m2	Distance (m) to 5 kW/m^2
1	579	970	2,270
2	709	1,110	2,640
3	205	460	1,020
4	324	650	1,460
5	458	820	1,900
6	696	1,090	2,600

8.0 IRA Results and Conclusions

The following section details the results of the consequence modeling and collision frequencies. Consequence results are depicted graphically on nautical charts.

8.1 Consequence Modeling Results

Thermal radiation hazard calculations from both pool fires and flammable vapor dispersion modeling to the lower flammability limit (LFL) were performed for the following LNG regasification vessel (LNGRV) release scenarios for the Port Ambrose deepwater (DWP) project:

- Scenario 1: Intentional attack leading to a 16 m^2 breach in a single LNGRV tank
- Scenario 2: Intentional attack leading to a 12 m^2 breach in two (2) LNGRV tanks
- Scenario 3: Hijacking attack leading to a 2 m^2 breach in a single LNGRV tank
- Scenario 4: Hijacking attack leading to a 5 m^2 breach in a single LNGRV tank
- Scenario 5: Hijacking attack leading to a 2 m^2 breach in two (2) LNGRV tanks
- Scenario 6: Vessel collision/allision leading to a 23.1 m^2 breach in a single LNGRV tank

Since the Independent Risk Assessment (IRA) defines and analyzes only the bounding intentional and vessel collision scenarios, the intentional scenario with the largest thermal radiation and flammable vapor dispersion results and the vessel collision scenario will be the focus of the Port Ambrose results. As detailed in Section 7 and presented below:

- Scenario 2 (Intentional attack leading to a 12 m^2 breach in two (2) LNGRV tanks) is the bounding intentional scenario for vapor cloud dispersion and thermal radiation at the DWP.
- Scenario 6 (vessel collision/allision with the LNGRV leading to a 23.1 m^2 breach) is the bounding accidental scenario for vapor cloud dispersion and thermal radiation at the DWP.

Scenarios 3 – 5 are additional intentional scenarios provided by Sandia for this DWP project. While the consequences were determined as part of the Phase I risk assessment, the hazard zones will be reviewed in detailed as part of the Phase II risk assessment. Therefore, the overlays for these three scenarios are not provided as results in Phase I since the location is not fixed. The Phase II risk assessment will used the hazards zones, as compared to the threat (to the port) and the vulnerabilities (based on the security measures for the project), to determine the risk for these scenarios and the need for additional security countermeasures.

8.1.1 Thermal Radiation Hazard Distances from Pool Fire

Thermal radiation hazard distances from a pool fire were estimated to two different heat flux levels:

- 37.5 kW/m^2: Damage to process equipment and storage tanks for unprotected exposures based on an average 10-minute exposure duration, as well immediate fatalities
- 5 kW/m^2: Permissible level for emergency operations lasting several minutes with appropriate clothing based on an average 10-minute exposed duration and onset of second degree burns based on an average 40-second exposed duration

Table 8-1 details the pool fire consequence results for the intentional (Scenario 1-2) and vessel collision (Scenario 6). This table details the number of tanks breached, release quantity (from the tank(s) breached), and distances to the 37.5kW/m^2 and 5kW/m^2 thermal radiation endpoints..

Table 8-1: Distances to Selected Thermal Radiation Hazard Levels

(Distances measured from the center of the pool)

Result	Scenario 1 (Intentional)	Scenario 2 (Intentional)	Scenario 6 (Collision)
Breach Size, m^2	16	12	23.1
Number of Tanks	1	2	1
Total Capacity of Impacted Tank(s), m^3	41,429	82,857	41,429
Release Quantity, m^3	29,000	58,000	29,000
Pool Fire Maximum Distance to Endpoint (meters)			
Pool Diameter, m	579	709	696
Thermal Radiation Endpoint > 37.5kW/m^2	970	**1,110**	1,090
Thermal Radiation Endpoint > 5 kW/m^2	2,270	**2,640**	2,600

The results and conclusions for this risk analysis have considered the most conservative thermal radiation distances. These results have been highlighted in bold-face type in Table 8-1. As shown, Scenario 2 is the bounding case for the intentional and accidental scenarios.

Sandia describes "zones" of risk to consider when evaluating risk reduction strategies for intentional and vessel collision spills of LNG:

- Zone 1: From ship to 37.5 kw/m2 – in this area, the risk and consequences of a large LNG spill could be significant and severe negative impacts; severe damage to structural including steel structures.
- Zone 2: From 37.5 kw/m2 to 5 kw/m2 area – the consequences of a large spill are of a varying damage; options for structural and personnel protection required or negatively impacted.
- Zone 3: Less than 5 kw/m2 – only minor impact on personnel if they move away from the fire.

8.1.2 Flammable Vapor Cloud Dispersion

The vapor cloud dispersion hazard distance was reported as the maximum downwind distance to the Lower Flammability Limit (LFL).

The flammable vapor cloud dispersion simulations were performed using FLACS. The distances to LFL predicted by FLACS for the intentional and accidental release scenarios are detailed in Table 8-2. All distances are measured from the center of the LNG pool.

Table 8-2: Distance to LFL

(Distance measured from the center of the pool)

Result	Scenario 1 (Intentional)	Scenario 2 (Intentional)	Scenario 6 (Collision)
Breach Size, m^2	16	12	23.1
Number of Tanks	1	2	1
Total Capacity of Impacted Tank(s), m^3	41,429	82,857	41,429
Release Quantity, m^3	29,000	58,000	29,000
Flammable Vapor Cloud Dispersion (No Ignition)			
Maximum Pool Diameter (m)	533	556	541
Distance to LFL, m	2,800	**3,550**	2,750

The major hazard of this consequence is the ignition and combustion of the flammable gas within the cloud--called a flash fire. A flash fire can result in potential impacts to the public and property. Due to the speed of the flame (as it propagates from the ignition source through the flammable range of the cloud), the impacts will be highly dependent on an individual's location (indoors vs. outdoors) and on the construction of the property exposed to the fire.

Thermal radiation effects from the vapor cloud fire can extend outside the flammable portion of the cloud and could result in a larger hazard distance as compared to the distance to LFL. But, due to the transient nature of this fire, the exposure duration from a flash fire is much shorter than exposure duration of a pool fire and is thus much shorter than the basis for the thermal radiation endpoints presented in Section 8.1.1. Assuming the flame acceleration of the flash fire is not impacted significantly by obstacles (consistent with the open nature of the DWP locations), the expected flame speed through the cloud could range from 8-17 m/s.[57] At these flame speeds, the exposure duration would not be significant, thus requiring a much higher thermal radiation exposure to result in comparable impacts to those listed in Section 8.1.1. Due to the uncertainty in the thermal radiation effects outside the flammable range of the vapor cloud, no additional thermal radiation has been considered and the hazard distances reported are limited to the distance to LFL.

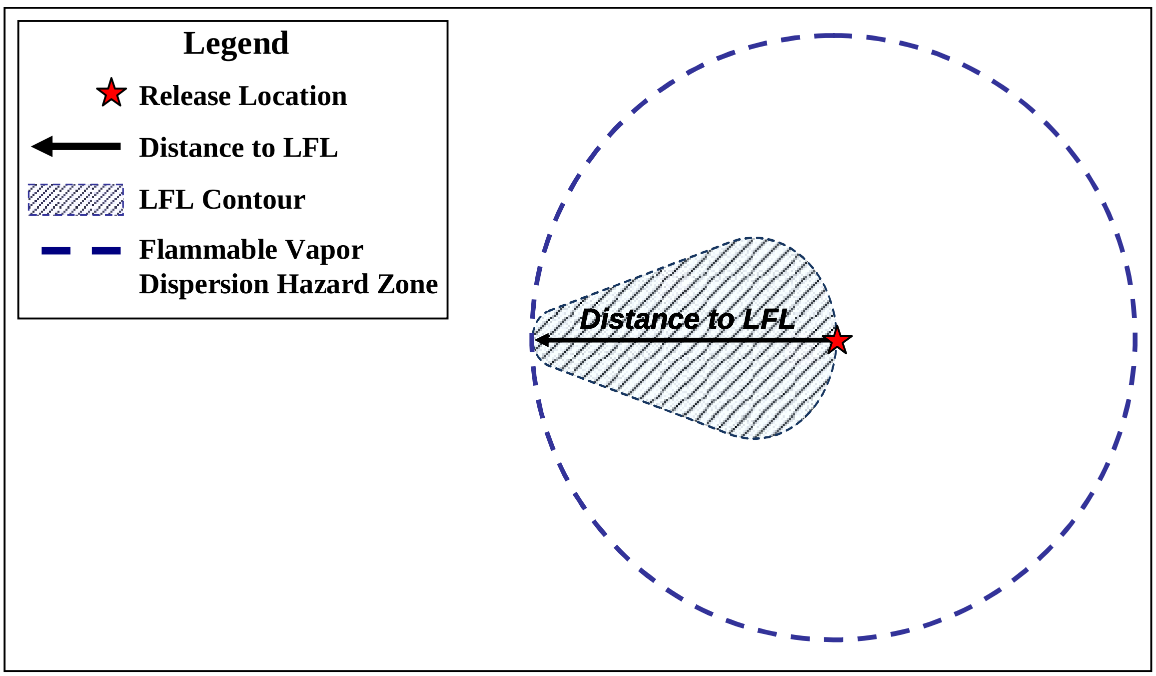
For both the thermal radiation and flammable vapor dispersion consequence results, the hazard zones are presented in Section 8.3 as overlays at the DWP buoy locations. As compared to the pool fire consequence, where the thermal radiation hazard extends radially from the pool fire center (assumed to be the ship), and the flammable vapor dispersion hazard will extend as a cloud dispersing in the downwind direction. Since the flammable vapor dispersion hazard zone is dependent on the wind direction at the time of release, the flammable vapor dispersion hazard zone overlays for the IRA are depicted as a circular area, with a radius equal to the maximum distance to the LFL, and centered at the spill location (assumed to be the ship). This representation of the flammable vapor hazard is independent of wind direction, illustrating the hazard from all wind directions.

[57] P.K. Raj, et al., *Experiments involving pool and vapor fires from spills of liquefied natural gas on water*, Arthur D. Little, ADA 077073, June 1979.

As shown in Figure 8-1, the actual hazard of the flammable vapor dispersion consequence is only in the downwind direction, and only within the LFL contour. The contour is the outer shape of the cloud out to a concentration equal to the LFL. As a result of the large release quantities and large pool sizes associated with the bounding cases of the IRA, the LFL contour (5% methane concentration level) does not result in a dispersion profile with a classical cigar/elliptical shape. This cloud shape is also illustrated in the CFD results in Section 7, showing that near the origin of the spill the shape of the cloud is dominated by heavy gas effects and, farther downwind the cloud transitions to the more classical dispersion profile, tapering off at the maximum LFL distance. It should be noted that the illustration in Figure 8-1 has not been drawn to scale, and only illustrates the portion of the cloud with a concentration greater than or equal to the LFL. The illustration is presented here to inform the public that while the hazard zone is overlaid as a circle in Figure 8-4 and Figure F (in the Executive Summary), not all portions within the circular hazard zone are expected to be impacted from a release.

Figure 8-1: Example Flammable Vapor Dispersion Hazard Zone

(Illustrated with predominate wind direction from the east)



8.2 Ship Collision Frequency Results

The total frequency of a collision with an LNGRV at the DWP was calculated for two vessel types: 1) vessels in the established Ambrose to Nantucket lane and Hudson Canyon to Ambrose lane; and, 2) vessels randomly passing the DWP location. This calculation utilized vessel traffic from the AIS dataset for this project and only included those vessels with the potential to breach the inner hull of the LNGRV in a collision.

Due to the distance between the DWP and the vessels in the two adjacent traffic lanes, the likelihood of a powered and drifting collision from vessels in these defined routes and the LNGRV was unlikely. In addition to vessels in the defined fairway, vessels of sufficient displacement and speed were identified that passed near the DWP. Using the collision frequency calculation for randomly distributed vessels, the likelihood for these vessels colliding with the DWP was calculated. However, given the small number of random vessels and the size of the LNGRV the likelihood is also unlikely.

The collision frequency for the proposed DWP considering both vessels in the two adjacent traffic lanes and randomly distributed around the DWP is shown in Table 8-3.

Table 8-3: Frequency of Vessel Collisions for Proposed DWP

TRAFFIC LOCATION	ANNUAL FREQUENCY OF COLLISION (COLLISION PER YEAR)	COLLISION ESTIMATED PERIOD (YEARS PER COLLISION)
Ambrose to Nantucket Lane	2.13×10^{-5}	1 collision every 47,000 years
Hudson Canyon to Ambrose Lane	7.98×10^{-9}	1 collision every 125,000 years
Randomly Distributed	1.67×10^{-8}	1 collision every 60,000 years
TOTAL	$\mathbf{2.13 \times 10^{-5}}$	**1 collision every 47,000 years**

8.3 Conclusions

The conclusions of the IRA are presented as the analysis of the following proposed Project combinations as specified by USCG:

- Alternative A: Baseline, no DWP built
- Alternative B: Port Ambrose built

If the Port Ambrose project is built (Alternative B), there is only one area where the potential hazard zones for thermal radiation and flammable vapor dispersion need to be considered and that is directly around the DWP buoys as illustrated by the consequence modeling zones. No results are shown for Alternative A (Baseline, no DWP built) as this alternative is simply the “as-is” case for this area and the proposed DWP location.

The conclusions of this risk assessment are presented as the hazard zones for thermal radiation hazard and vapor cloud dispersion for the worst case bounding scenarios evaluated. The hazard zones have been presented as graphical overlays on the nautical chart for the proposed DWP project location. The results of the Port Ambrose IRA are presented without passing judgment on the merits of the applicant’s proposed DWP. While the IRA evaluated the potential impacts to the public or surrounding infrastructure, it did not attempt to predict the number of estimated fatalities or injuries from these events. Also, the IRA was completed without considering any mitigation measures that could be implemented to reduce the risk of accidental or intentional release of LNG from this proposed project.

For reference, two thermal radiation endpoint levels are evaluated and presented and are defined as:

- 37.5 kW/m^2: Damage to process equipment and storage tanks for unprotected exposures based on an average 10-minute exposure duration, as well immediate fatalities
- 5 kW/m^2: Permissible level for emergency operations lasting several minutes with appropriate clothing based on an average 10-minute exposed duration and onset of second degree burns based on an average 40-second exposed duration

The pool fire calculations report the distance to each of these two thermal radiation hazard zones estimated, respectively, from the LNGRV release location, and measured from the center of the pool fire. The vapor cloud dispersion hazard distance was determined as the maximum downwind distance to the Lower Flammability Limit (LFL).

The proposed Port Ambrose falls within the proposed area of interest for the wind energy project(s) proposed for offshore New York as described in the Bureau of Ocean Energy Management's Call for Information of May 28, 2014 (79 FR 30645). The risk assessment will take this proposal into account; however, because of the lack of wind energy specific project details, this report is necessarily constrained in its ability to provide an analysis of the navigational safety risks that operation of the deepwater port may have on a future wind farm siting and operation. While it would be inappropriate for this report to purport to establish specific setbacks between the deepwater port, vessels operating in the area, and the wind farm, this report does provide information on LNG spill consequences which will help inform any future offshore wind energy project proponent on future siting of wind turbines.

To the extent practicable, in the absence of a detailed wind farm application, the Phase II portion of the IRA will examine navigational safety concerns and consider applicable measures that may serve to mitigate potential risks of both facilities operating in the same geographic area

8.3.1 Port Ambrose DWP Area Consequence Results

This section presents the thermal radiation and flammable vapor dispersion hazard zones at the Port Ambrose DWP buoy locations. As discussed in this report, the project consists of two buoy locations (Buoy #1 and Buoy #2) where an LNGRV can be moored, regasify LNG, and distribute natural gas into the subsea pipeline to shore. A summary table detailing the consequence modeling results for the bounding release scenarios evaluated in the risk assessment is presented in Table 8-4.

The pool fire and thermal radiation results for Scenarios 2 and 6 are shown in Figure 8-2 and Figure 8-3, respectively. These scenarios represent the bounding thermal radiation hazards for the intentional and vessel collision scenarios. In Figures 8-2 and 8-3, the consequence is shown as the radial distance overlaid and centered at the buoy locations to the two thermal radiation hazard endpoints. The hazard zones of Scenario 2, modeled as an intentional 12 m^2 breach in two of the LNG compartments of an LNGRV, and the thermal radiation zones for Scenarios 6 (vessel collision). Scenario 2 resulted in larger hazard zones. As shown in Table 8-4, the thermal radiation distances for Scenario 2 extend 1,110 meters to 37.5 kW/m^2 and 2,640 meters to 5 kW/m^2. For Scenario 6, the distances are 1,090 meters to 37.5 kW/m^2 and 2,600 meters to 5 kW/m^2. These results and graphical overlays illustrate that a pool fire at either Buoy #1 or Buoy #2 would not impact the other buoy location from a sustained fire at the 37.5 kW/m^2 and 5 kW/ m2 radiation levels. Additionally, as shown, the safety fairway is not impacted at these radiation levels.

Table 8-4: Consequence Modeling Summary Results

(Distances measured from the center of the pool)

Result	Scenario 1 (Intentional)	Scenario 2 (Intentional)	Scenario 6 (Collision)
Breach Size, m^2	16	12	23.1
Number of Tanks	1	2	1
Total Capacity of Impacted Tank(s), m^3	41,429	82,857	41,429
Release Quantity, m^3	29,000	58,000	29,000
Pool Fire Maximum Distance to Endpoint (meters)			
Pool Diameter, m	579	709	696
Thermal Radiation Endpoint > 37.5kW/m^2	970	1,110	1,090
Thermal Radiation Endpoint > 5 kW/m^2	2,270	2,640	2,600
Flammable Vapor Cloud Dispersion (No Ignition)			
Maximum Pool diameter (m)	533	556	541
Distance to LFL, m	2,800	3,550	2,750

Figure 8-4 compares the flammable vapor dispersion results for Scenarios 2 and 6, represented as the distance to the LFL overlaid at the DWP buoy locations. As compared to the pool fire consequence, where the thermal radiation hazard extends radially from the pool fire center, the flammable vapor dispersion hazard will extend as a cloud dispersing in the downwind direction. The flammable vapor dispersion hazard (distance to LFL) is illustrated as a circle, since the cloud could disperse in any of 360 degrees, depending on the wind direction at the time of release, as illustrated in Figure 8-1. This dispersion in the downwind direction is also illustrated as a plume from the predominant wind direction (from the south).

As illustrated in Figure 8-4, the intentional scenario (Scenario 2) results in the greatest distance to LFL, and an intentional incident at either buoy could potentially impact the other buoy location (see Figure 3-5). However, given a dispersion duration of over 20 minutes to the other buoy location, the other LNGRV has an emergency buoy disconnect that can shutdown regasification and disconnect the LNGRV in 15 minutes.

In addition to impacting the other buoy, the dispersion distance to LFL from Scenario 2 (from Buoy #2) could also impact Ambrose to Nantucket lane, depending on the wind direction (see Figure 3-5) at the time of release. As discussed above, a similar dispersion time of over 20 minutes is predicted for the cloud to reach the shipping lane.

Figure 8-2: Port Ambrose DWP (Thermal Radiation Hazard Zones - Scenario 2)

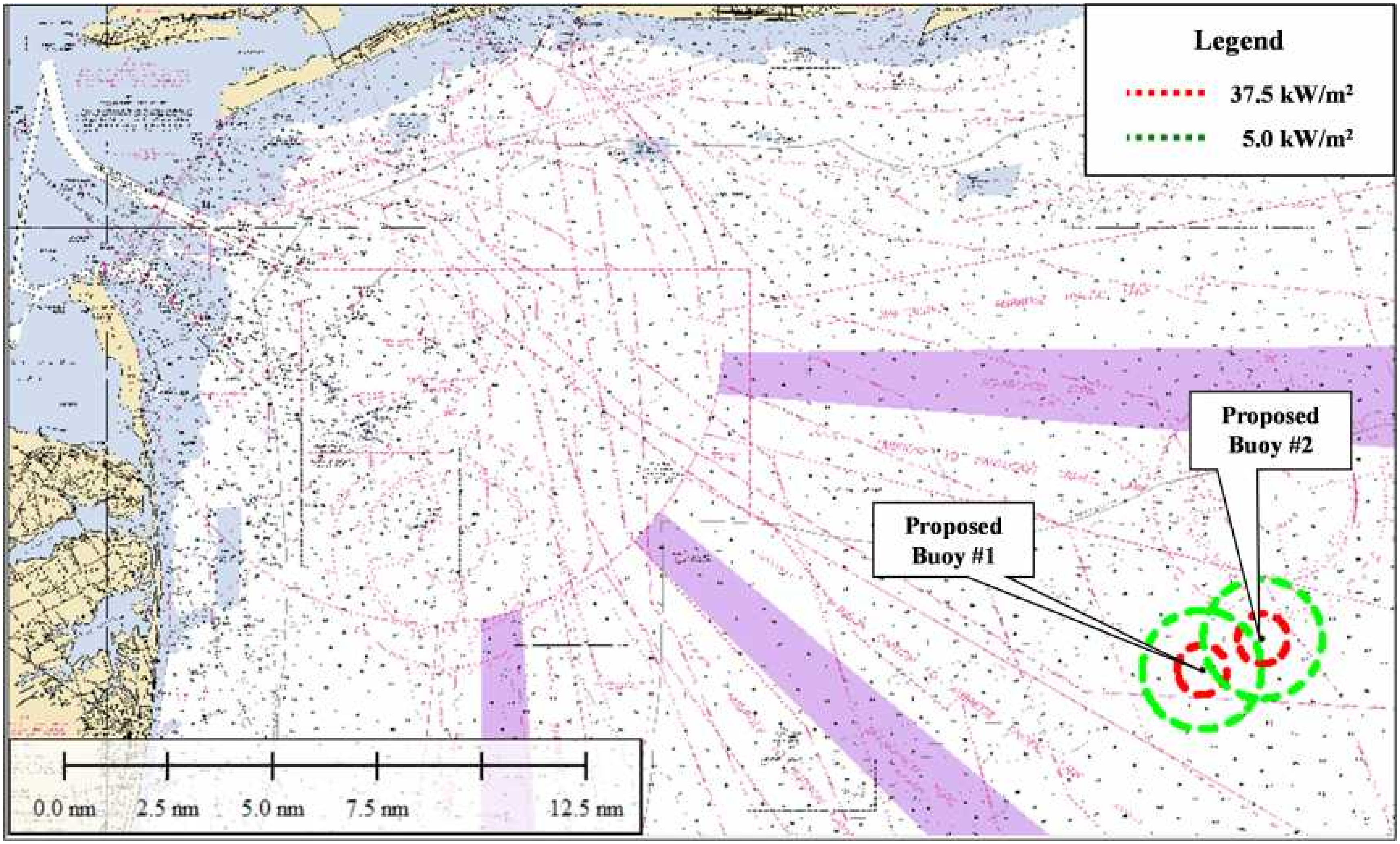


Figure 8-3: Port Ambrose DWP (Thermal Radiation Hazard Zones - Scenario 6)

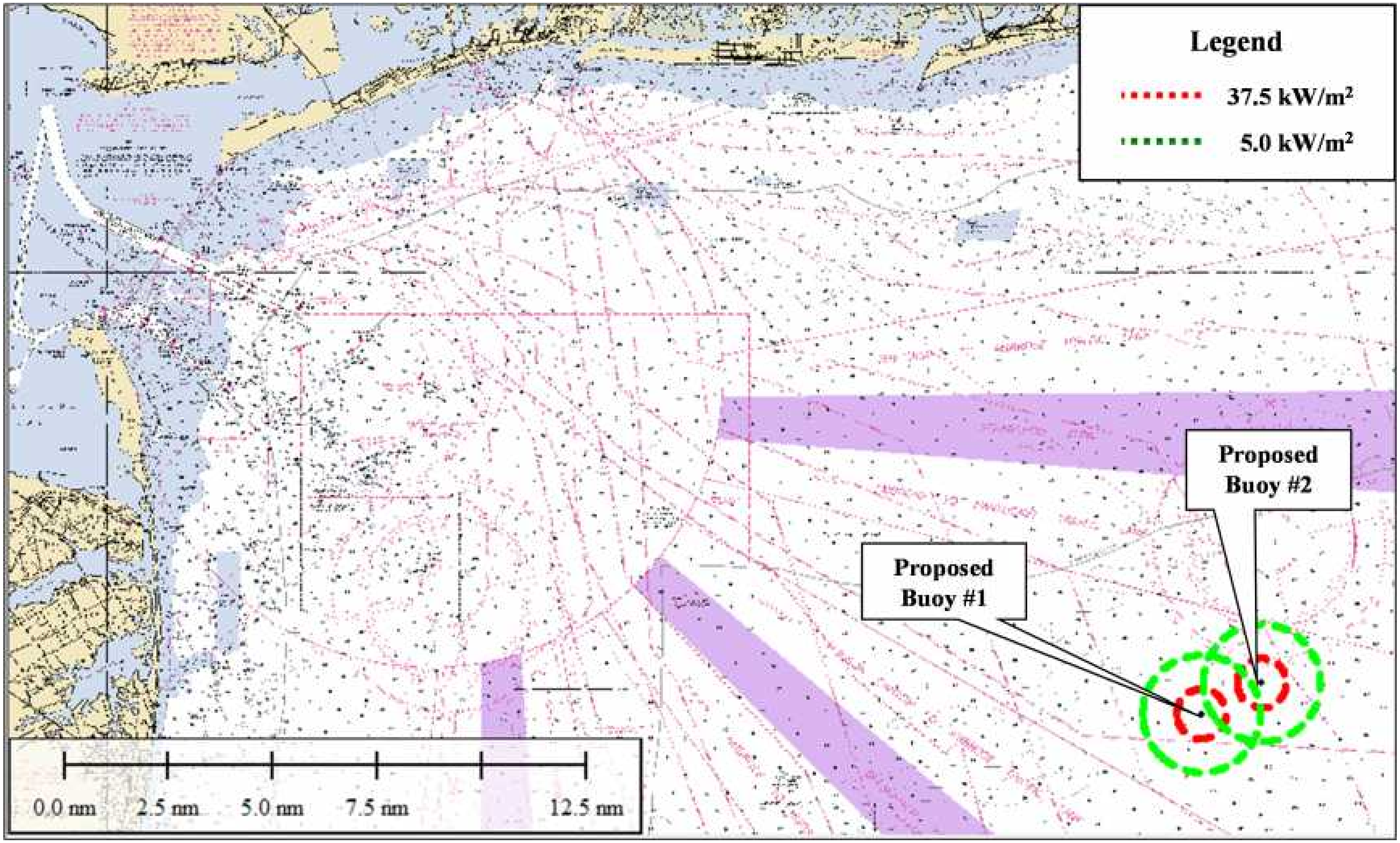
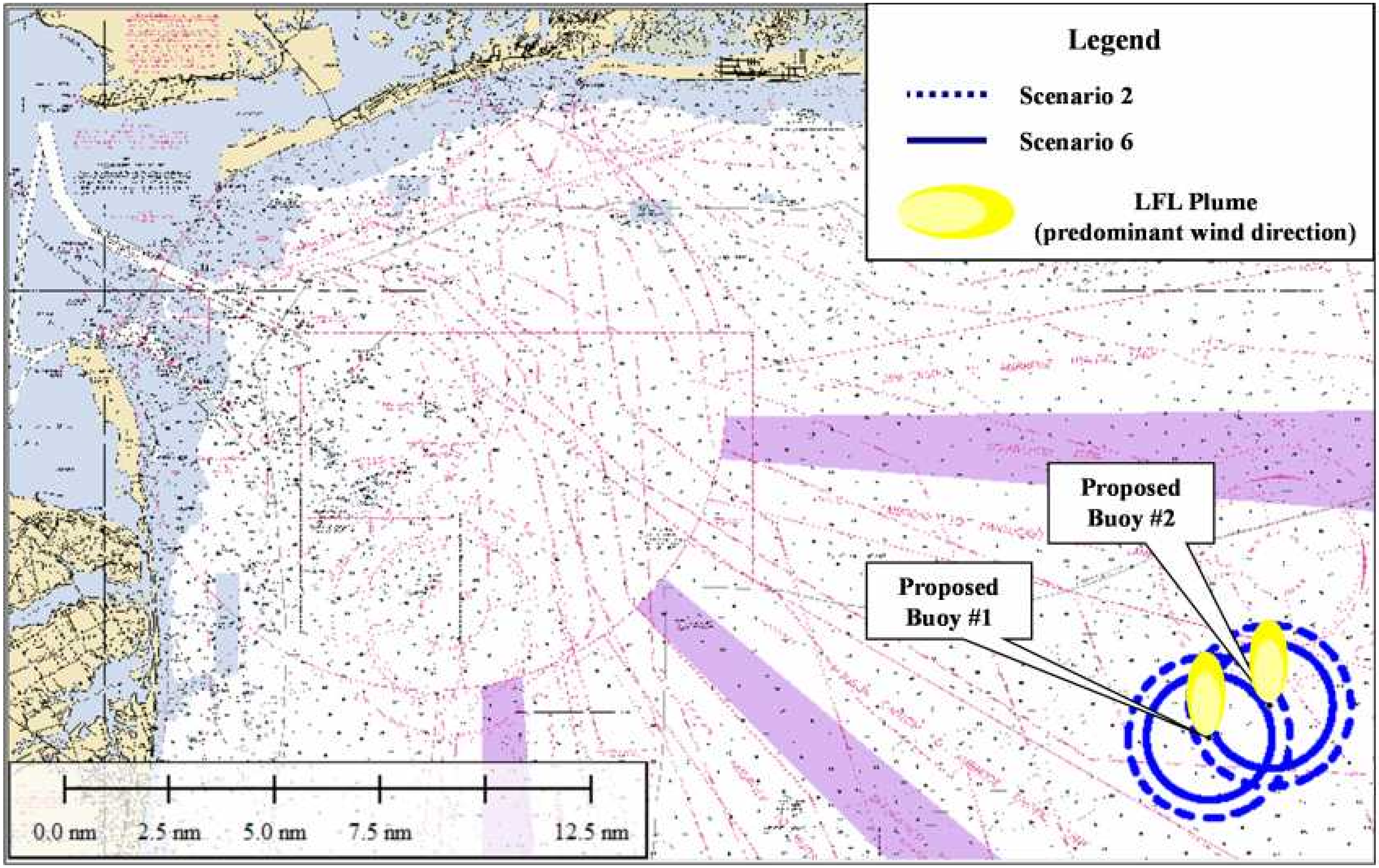


Figure 8-4: Port Ambrose DWP Vapor Cloud Dispersion - Distance to LFL



References

8.4 Standards:

- Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (Gas Carrier Code), 1983
- 1994/1996 Amendments to the IGC (replaced the Gas Carrier Code)
- DNV OS-F101, Det Norske Veritas, Submarine Pipeline Systems
- International Code for Ships Carrying Liquefied Gases in Bulk (International Gas Code [IGC]) 1993.
- International Convention for the Prevention of Collisions at Sea (COLREG)
- International Convention for the Safety of Life at Sea (SOLAS) (1974/1981)
- International Convention on Standards of Training, Certification and Watchkeeping (STCW) for Seafarers, 1978
- International Management Code for the Safe Operation of Ships and for Pollution Prevention (International Safety Management Code [ISM Code], adopted by IMO Resolution A.741 (18) in 1994
- International Safety Management Code

8.5 Regulatory References:

- Deepwater Port Act of 1974 as amended by the Maritime Transportation Security Act of 2002; (33 United States Code 1501)
- LNG Facilities: Federal Safety Standards (49 CFR 193)
- Maritime Transportation Security Act of 2002 (MTSA)
- Natural Gas Pipeline Safety Act of 1968, as amended, (NGPSA) and Hazardous Liquid Pipeline Safety Act of 1979 as amended (HLPSA) both recodified as 49 U.S.C. Chapter 601
- National Environmental Policy Act (NEPA)
- Notice of Availability of Detailed Computations for the Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers, Federal Energy Regulatory Commission, Docket No. A04-6-000, June 29, 2004.
- Title 33 USC 1501 (Deepwater Port Act of 1974 as amended by the Maritime Transportation Security Act of 2002)
- Title 49 CFR 190-199 (Pipeline Safety Programs)
- Title 49 CFR 193.2057 (Liquefied Natural Gas Facilities: Federal Safety Standards -- Thermal Radiation Protection)
- Title 49 CFR 193.2059 (Liquefied Natural Gas Facilities: Federal Safety Standards -- Flammable Vapor-Gas Dispersion Protection)

Appendix O

LNG Facility and Carrier Safety Record

LNG Land-Based Facility Safety Record

A review of available information is limited to land-based LNG facilities and indicates there have been only seven documented incidents with one or more (worker and/or public) fatalities associated directly with operations at land-based LNG facilities; (1) Skikda, Algeria, Jnauary 2004; (2) Bontang, Indonesia, (3) Maryland, United States, 1979; (4) Arzew, Algeria, 1977; (5) New York, United States, 1973; (6) Raunheim, Germany, 1966; and (7) Ohio, United States, 1944. Two of the seven incidents were related to construction or maintenance activities at the LNG facilities and not directly to LNG operations (CH-IV International 2006). These incidents include:

- **Skikda, Algeria, January 2004**. Available reports suggest that a gas cloud of unknown origin found a source of ignition in a boiler resulting in a large fire. Twenty-seven individuals were killed in the incident. The preliminary investigation suggests more liberal use of gas detection instruments in LNG facilities as a preventative measure, especially in the vicinity of air intake devices (CEC 2004; Kornfield et al. 2004).
- **Bontang, Indonesia, 1983**. An overpressure explosion occurred due to a valve being inappropriately in the closed position during facility maintenance. Three individuals were killed. Industry analysts have classified this as a maintenance accident since no LNG was present in the system (CH-IV International 2006). Current standards and practices for management of valves in relief systems should prevent recurrence of such an incident.
- **Maryland, U.S., 1979**. An explosion occurred in an electrical substation at a LNG receiving terminal. One individual was killed. No gas detection system was installed in the substation because natural gas was never expected to enter. As a result of the incident, design code changes were made and applied industry-wide (CH-IV International 2006).
- **Arzew, Algeria, 1977**. Due to the rupture of a cast aluminum valve, LNG was released from an inground storage tank. One worker was killed. Industry standard practice now is to use stainless steel for fabrication of large valves (CH-IV International 2006).
- **Staten Island, New York, U.S., 1973**. A LNG tank was out-of-service for repairs. Mylar and foam liner materials ignited, leading to temperature rise and pressure surge. The pressure surge caused a roof collapse, killing 37 workers who were inside the tank. The investigation classified this as a construction accident, not a LNG accident (CH-IV International 2006). Compliance with OSHA requirements for confined space entry and hot work should prevent recurrence of such an incident.
- **Raunheim, Germany, 1966.** Accidental venting occurred while LNG was being passed through a vaporizer that used a liquid level controller to operate below its maximum capacity of 4000 kg. The resulting vapor cloud drifted towards a control room resulting in fire and explosion, killing one. It was determined that the liquid level failed and as a result around 500 kg of LNG was vented out of the vaporizer (ÅF Industry AB and SSPA Sweden AB 2011).
- **Cleveland, Ohio, U.S., 1944.** A LNG storage tank built with low-nickel content steel failed shortly after being placed into service, resulting in a leak and subsequent fire that killed 128 people. The investigation concluded that, had the tank been built to code, the accident would not have occurred (CH-IV International 2006).

LNG Carrier Safety Record

Year	LNG Carrier	Incident
2012	*LNG Aries*	On June 20, 2012 off the coast of Oman, pirates attacked the Aries with rocket propelled grenades and small arms fire. The pirates moved to within 50 meters and fired shots, of which three rounds hit the tanker and damaged it. No one was injured during the attack and the LNGC evaded hijack. The LNGC was classified as safe and continued its scheduled voyage from Port Said to Suez.
2006	*Golar Freeze*	The LNGC moved away from its docking berth during unloading on March 14, 2006 in Savannah, Georgia. The powered emergency release couplings on the unloading arms activated as designed and transfer operations were shut down.
2004	*Tenaga Lima*	The *Tenaga Lima* grounded on rocks while proceeding to open sea east of Mopko, South Korea due to strong current in November 2004. The shell plating was torn open and fractured over an approximate area of 20 feet by 80 feet, and internal breaches allowed water to enter the insulation space between the primary and secondary membranes. The ship was refloated, repaired and returned to service.
2002	*Norman Lady*	The USS Oklahoma City nuclear submarine struck the *Norman Lady* while rising to periscope depth near the Strait of Gibraltar in November 2002. The 87,000 m^3 LNG tanker, which had just unloaded its cargo at Barcelona, Spain, sustained only minor damage to the outer layer of its double hull with minor leakage of seawater into the double bottom ballast tanks. No damage to the inner hull or the cargo system and tanks occurred.
2002	*Mostefa Ben Boulaid*	LNG spill onto its deck during loading operations in Algeria in 2002. The spill, which is believed to have been caused by a check valve leak, caused brittle fracturing of the steelwork. The ship's emergency shutdown system, water spray system and response of the crew resulted in a minimum of serious damage. Current ship design includes protective cryogenic metal protective plates under the transfer area, usually with a water flow, which protects the ship’s deck. The ship was required to discharge its cargo, after which it proceeded to dock for repair.
2001	*Khannur*	A cargo tank overfilled into the ship’s vapor handling system on September 10, 2001 during unloading at Everett, Massachusetts as a result of a malfunctioning valve. Approximately 100 gallons of LNG were vented and sprayed onto the protective decking over the cargo tank dome, resulting in several cracks. After re inspection by the USCG, the *Khannur* was allowed to discharge its LNG cargo.
2001	*Methane Polar*	The ship collided with the bulk cargo ship Eastwind about 34 miles off the Algerian Coast. Although the *Methane Polar* sustained some damage, it remained in a stable condition and was later repaired. The Maritime and Port Authority stated that there were no reports of any cargo release or pollution from the collision.
1989	*Tellier*	The *Tellier* was blown from its docking berth at Skikda, Algeria in February 1989 during severe winds causing damage to the loading arms and the ship and shore piping. The cargo loading had been secured just before the wind struck, but the loading arms had not been drained. Consequently, the LNG remaining in the loading arms spilled onto the deck causing fracture of some plating. As a result of this incident, LNG loading arms are now fitted with ship position monitoring devices, including transfer shutdown and emergency “dry break” couplings for disconnection of the loading arms.
1985	*Isabella*	LNG spilled onto its deck due to a cargo tank overflow in June 1985, causing severe cracking of the steelwork. The spill had been attributed to a cargo valve failure during discharging of cargo.
1980	*LNG Taurus*	The *LNG Taurus* grounded in December 1980 near the entrance to Taboata Harbor, Japan. The grounding resulted in extensive bottom damage, but the cargo tanks were not affected. The ship was refloated and the cargo unloaded.
1980	*LNG Libra*	The propeller shaft fractured while the ship was en route to Japan with a full cargo in October 1980. The ship was taken under tow, and the cargo was safely transferred to another LNG ship and delivered to its destination.

Year	LNG Carrier	Incident
1979	*El Paso Paul Kayser*	The ship grounded on a rock pinnacle in June 1979 in the Straits of Gibraltar during a loaded voyage from Algeria to the United States. Extensive bottom damage to the ballast tanks resulted; however, the cargo tanks were not damaged, and no cargo was released. The complete cargo of LNG was subsequently transferred to another LNG ship and delivered to its U.S. destination. The *El Paso Paul Kayser* proceeded to a shipyard under its own power with temporary repairs. LNG carriers are presently equipped with sophisticated navigation systems, including global positioning systems, which provides the ship's captain with the ship's exact position.
1979	*Pollenger*	A LNG spill onto the steel cover of cargo tank number one occurred while unloading at Everett, Massachusetts in April 1979. The spill caused cracking of the steel plate.